THE IMPACT OF COMPUTERISED PHYSICIAN ORDER ENTRY WITH INTEGRATED CLINICAL DECISION SUPPORT ON PHARMACIST-PHYSICIAN COMMUNICATION IN THE HOSPITAL SETTING

By

SARAH KATIE PONTEFRACT

A thesis submitted to the
University of Birmingham for the degree of
DOCTOR OF PHILOSOPHY

School of Pharmacy
Institute of Clinical Sciences
College of Medical and Dental Sciences
University of Birmingham
July 2017

Abstract

Computerised Physician Order Entry (CPOE) and clinical decision support has been shown to have some unintended and unanticipated consequences, such as on communication and coordination of care. I set out to investigate whether CPOE has an impact on communication between pharmacists and physicians in the hospital setting.

An analysis of over 34,000 free-text messages assigned by pharmacists to prescription orders over a 12-month period showed a sub-optimal exchange of information with the physician. Focus groups and observational research were conducted to provide a more in-depth understanding of the factors involved. The use of CPOE did not reduce opportunities for personal interaction. The capability to communicate electronically facilitated a non-interruptive workflow, beneficial for staff time and for limiting distractions. It also improved clinical documentation, which helped coordinate care of patients between members of the pharmacy team. However, the research identified several barriers to the effectiveness of communication via the CPOE system, including: the increased frequency of messages sent; poor display characteristics of the message; poor access to information to inform decision-making; one-way communication; and no assigned responsibility to respond. These factors need to be considered in the design of systems and supported by interprofessional training to optimise communication between the professionals.

Word count: 73,205 excluding tables and appendices

For my family, friends and colleagues

Acknowledgments

There have been many people at home and at work that have provided me with endless support and encouragement during the completion of this PhD. This is never more important than when completing it part-time, where the thesis never leaves the list of things to do.

First, I would like to thank the National Institute for Health Research, who awarded me with the funding to complete my PhD as a Doctoral Research Fellow. This provided me with access to incredible training and networking opportunities, for which I am eternally grateful.

I would like to thank my supervisor Prof Jamie Coleman, who nudged me into commencing a PhD when I took on the role of research pharmacist for the Collaboration for Leadership in Applied Health Research and Care (CLAHRC) programme, which I (naively) agreed would be a great idea. Jamie has been an incredible support, both personally and professionally and has provided ongoing invaluable guidance based on his own research experience and subject expertise. Thank you to my supervisor Prof John Marriott, who instilled a good PhD work ethic of little and often and challenged me to philosophise. Thank you to Dr Sabi Redwood who has taught me a great deal about undertaking qualitative research. Thank you for inspiring me, for helping me see the bigger picture and for keeping me on track.

I would like to thank Mr James Hodson, without whom I fear I would still be drowning in statistical text books. James provided endless support for the quantitative element of my research; and although it may not be reciprocated given my endless questions, I thoroughly

enjoyed working with him and have a great deal of respect for his statistical knowledge and ability to communicate this.

I would like to thank the pharmacists and physicians at the University Hospital Birmingham and Guy's and St Thomas' NHS Foundation Trust for participating in the focus groups and observational research, without whom this study would not have been possible.

Finally, I am very grateful to my colleagues Hannah Vallance, Hannah Brooks and Sonal Shah for their support over the years with cups of tea and humour.

Authorship statement

This PhD represents independent research funded by the National Institute for Health Research (NIHR). The views expressed are my own and not necessarily those of the National Health Service, The NIHR or the Department of Health.

Throughout the thesis, chapters or sections of chapters have been prepared for publication and published in peer-reviewed journals. This was carried out in accordance with requirements from the National Institute for Health Research Doctoral Fellowship. Where sections have been published, these have been referenced at the beginning of each chapter and summarised in the appendices.

During the completion of this thesis, my surname changed from 'Thomas' to 'Pontefract' and as such, publications exist under both surnames.

Contents

List of figures

List of tables

List of appendices

Glossary of abbreviations

ADR	Adverse drug reaction
ADE	Adverse drug event
ASHP	American Society of Hospital Pharmacists
BNF	British National Formulary
CBWA	Context-based workplace awareness
CDS	Clinical decision support
CDU	Clinical decision unit
CNS	Central nervous system
CPOE	Computerised physician order entry
CWR	Collaborative working relationship
DDI	Drug-drug interaction
DRP	Drug related problem
EEEO	Eye, ear, nose and oropharynx
EMA	European Medicines Agency
EPR	Electronic patient record
HFE	Human Factors Engineering
FTE	Full time equivalent
GMC	General Medical Council
GI	Gastrointestinal
GSTFT	Guy's and St Thomas' NHS Foundation Trust
MAOI	Monoamine oxidase inhibitor
NCC MERP	The National Coordinating Council for Medication Error Reporting and Prevention
OGU	Obstetrics, gynaecology and urinary-tract disorders

MHRA	Medicines and Healthcare products Regulatory Agency
NHS	National Health Service
UK	United Kingdom
US	United States
NMP	Non-medical prescriber
NRLS	National Reporting and Learning Service
NPSA	National Patient Safety Agency
PCNE	Pharmaceutical Care Network Europe
PICS	Prescribing, Information and Communication System
PI-Doc	Problem Intervention Documentation
SBAR	Situation, Background, Assessment and Recommendation
SSRI	Selective serotonin re-uptake inhibitor
TCA	Tricyclic antidepressant
TDM	Therapeutic drug monitoring
TdP	Torsades de Pointes
TNO	Trauma and Orthopaedics
TTO	To take out
UHBFT	University Hospital Birmingham NHS Foundation Trust
WHO	World Health Organisation

Chapter 1 INTRODUCTION

In this chapter, I provide a background to the themes that underpin the research question and the chapters of the thesis. I introduce the prescribing landscape in the United Kingdom (UK) hospital setting and discuss the role of the pharmacist. I discuss the national and international drivers to implement health information technology and the intended and unintended consequences of such interventions. Finally, I describe the aims and objectives of the research and outline the structure of the thesis.

1.1 The medication process

Pharmacological therapy remains the most common therapeutic intervention in the modern National Health Service (NHS) and the use of medicines is increasing year-on-year, largely due to an ageing population living with multiple morbidities (NHS England, 2014a). The cost of prescribing is also increasing year on year—£16.8 billion was spent on medication in 2015–16 (45% of which was in the hospital setting), compared to £13.0 billion in 2010–11 (Health and Social Care Information Centre, 2016).

The medication process comprises the steps of prescribing, the pharmacist's clinical check (validation), dispensing, administration and ongoing monitoring for the beneficial and

adverse effects of treatment. Viewed in its simplest form, the central roles of the three main healthcare professionals that interact with the process in the hospital setting may be considered as: 1) the physician writing or generating the prescription order for a patient; 2) the pharmacist validating and supplying the medicine; and, 3) the nurse administering the medicine. The process is far from simple though; the provision of pharmacological therapy to hospitalised patients is a complex and dynamic process that involves many healthcare professionals at each of the stages. The roles of those involved are also evolving, with many nurses and pharmacists now qualified as prescribers in the NHS and the role extending to allied healthcare professionals such as physiotherapists (Cooper *et al.*, 2008). This transformation of the medication process and change in skills mix means that many more professionals interact with the medication process in modern healthcare settings. Although intended to improve service delivery for patients, the articulation of the process may also introduce vulnerabilities, with an increased risk for error.

1.1.1 Medication errors

Medication errors are defined as *"a failure in the treatment process that leads to, or has the potential to lead to, harm to the patient"* (Ferner & Aronson, 2000). Errors can occur at any stage of the medication process, can cause serious harm to patients and are largely preventable. Errors and the associated harms are also a financial burden for healthcare organisations, costing an estimated $42 million each year worldwide (World Health Organization, 2017). In the UK, medication-related incidents account for approximately 10% of all adverse events reported to the National Reporting and Learning System (NRLS), listed in the top four most common incident types (NHS England, 2017). This figure is likely to

underestimate the true scale of the problem, since the statistics reported are completely dependent on the voluntary reporting of incidents and therefore an ethos of transparency amongst individuals and the organisation. A comprehensive review of patient safety incidents reported to the NRLS between 2005 and 2010 found that errors relating to the administration and prescribing of medicines were the most frequently occurring (Cousins *et al.*, 2012). Owing to the scale of the problem worldwide, in March 2017 the World Health Organisation (WHO) identified errors in this process as one of their global patient safety challenges; *"Medication without harm",* which aims to halve mediation-related incidents by 2022 (World Health Organization, 2017).

1.1.2 Hospital pharmacists

In the UK, hospital pharmacists work closely and collaboratively with medical and nursing staff to ensure patients receive safe and effective treatment(s) that will optimise outcomes. Pharmacists work on inpatient wards—and increasingly in outpatient clinics—in close proximity to the multidisciplinary teams and the patient and their carer/relative (Royal Pharmaceutical Society, 2014). This is usual practice in the UK and a norm prompted by NHS reports that foresaw pharmacists having the skills and knowledge to play an integral role in delivering a plan for reform of the NHS (Department of Health., 2000).

One of the main roles of a pharmacist is to perform a clinical check of prescriptions that require supply (Royal Pharmaceutical Society, 2016; p 10). This is conducted to ensure the prescription is safe for a patient and takes into account patient demographics, the medical history, the history of any presenting complaint and any concomitant treatment(s). In the

hospital setting, pharmacists spend a proportion of their time undertaking medicines reconciliation, "*the process of identifying an accurate list of a person's current medicines and comparing them with the current list in use, recognising any discrepancies and documenting any changes*" (National Institute for Health and Care Excellence, 2015). Reconciliation involves collecting and verifying patient information to identify intentional and non-intentional discrepancies—ideally within 24 hours of admission—and documenting and communicating this to ensure patients' regimens reflect those taken prior to admission. It is conducted because evidence suggests that up to 50% of inpatient drug charts contain errors and that these are most likely to occur on admission to hospital (Basey *et al.*, 2013). Pharmacist involvement early on in the process can reduce the rate of discrepancies and risk of patient harm. Pharmacist-led medicines reconciliation and history taking have also been shown to provide a more accurate outcome, compared to when the two are completed by nurses and physicians, possibly because of their training, familiarity with medicines and information gathering skills (De Winter *et al.*, 2010). The difference in accuracy may also be because pharmacists have more time to dedicate to this process.

Hospital pharmacists spend a proportion of their time conducting 'medication reviews'. This encompasses the clinical check, but also considers the stage of administration. The review takes into account factors such as the timing and duration of regimens, adherence to treatment, omitted and delayed medicines and any medicines the patient has on their person (prescribed, purchased over-the-counter or even recreational) (Royal Pharmaceutical Society, 2012). The process of clinical check, reconciliation and medication review require a great deal of information gathering, both from the patient (or their relative/carer) and other

healthcare professionals. It can also include the use of health information databases and pharmaceutical resources, such as the British National Formulary (BNF).

There is a wealth of research that supports the role of the pharmacist, particularly those that are ward-based and working in partnership with physicians. Pharmacists can identify prescribing errors and rectify unintended discrepancies before they reach the patient (Dornan *et al.*, 2009; Marvin *et al.*, 2016). In one study by Dornan *et al* (2009), hospital pharmacists in 19 acute NHS hospitals detected 11,000 prescribing errors over just seven days. Their interventions—defined as "*any proactive or reactive (in response to a question from another healthcare professional) activity undertaken by the pharmacist to suggest changes in drug therapy or monitoring, which involved contacting medical or nursing staff*" (Barber *et al.*, 2006), or perhaps more simply a request for a *"change in a patient's management or therapy" (Dooley et al., 2004)*—can reduce the risk of patient harm and adverse drug events. Evidence also suggests that the presence of a ward-based pharmacist can reduce readmissions to hospital and lower patient morbidity (Creswick and Westbrook, 2015; Gillespie *et al.*, 2009) and that their interventions can save money for the health service (Gallagher *et al.*, 2014). Their impact on the medication process is probably greatest when the pharmacist is part of the multidisciplinary team (Langebrake & Hilgarth, 2010). Research conducted in Australia also shows that the pharmacist acts as a *"hub"* of information and advice on wards for both nurses and physicians (Creswick and Westbrook, 2015).

1.2 Health Information Technology

1.2.1 Computerised Physician Order Entry

Computerised Physician Order Entry (CPOE)—more commonly referred to as electronic prescribing (ePrescribing) or Electronic Prescribing and Medicines Administration (EPMA) in the UK—is defined as: "*the utilisation of electronic systems to facilitate and enhance the communication of a prescription order, aiding the choice, administration and supply of a medicine through knowledge and decision support and providing a robust audit trail for the entire medicines use process*" (NHS Connecting for Health, 2009). It is part of an electronic patient record (EPR), specifically designed to document and facilitate the medication process. In the UK, the term CPOE does not entirely reflect the operation of the system in practice since other healthcare professionals (e.g. pharmacists and nurses) can also generate orders. Many systems have integrated Clinical Decision Support (CDS) systems, which are designed to facilitate clinical decision-making at the point of care through the connection of patient information, a pre-configured knowledge base and occasionally the demographics of the user (Beeler *et al.*, 2014; Shortliffe, 1987).

Studies conducted in the United States (US) in the late 1990s found that CPOE could reduce medication errors with potential for harm by between 55% and 88% (Bates *et al.*, 1998; Bates *et al.*, 1999). More recent studies show a consistent, albeit slightly smaller reduction, with CPOE associated with almost half as many medication errors (Nuckols *et al.*, 2014; Radley *et al.*, 2013; Ranji *et al.*, 2014). Of course, the reduction in error rates observed in sites is variable, depending on the complexity of the system(s) in use, the methods adopted

for data collection and the baseline error rate of the site (Barber *et al.*, 2006; Shamliyan *et al.*, 2008). As more patient information is digitised, the more the technology has the potential to improve health outcomes for patients. Electronic patient records enable real-time sharing of information across the interface of care and importantly with patients, to inform decision-making and empower self-management (Lee *et al.*, 2015; Liddell *et al.*, 2008; National Information Board, 2014). It is not surprising then that evidence also suggests that CPOE can have a positive impact on reducing the length of stay of patients in hospital and reduce patient mortality (Lyons *et al.*, 2017). Although perhaps not the main driver, CPOE also has significant financial benefits for healthcare organisations. A review commissioned by the Department of Health (UK) identified cost savings of £270 million each year if CPOE was implemented across NHS hospitals, as well as electronic prescription services in the community setting, where NHS prescriptions can be sent electronically to a nominated pharmacy for dispensing. In addition, the capability to integrate Electronic Patient Records (EPRs) across settings is reported to save a further £560 million each year (PricewaterhouseCoopers LLP, 2013).

Given the proven benefits of CPOE on rates of medication errors and the safety and quality of care for patients, financial incentives have been and continue to be offered to healthcare organisations to encourage the implementation of health information technology. In the US (2009), the Health Information Technology for Economic and Clinical Health Act (HITECH) permitted financial payments for organisations that implemented certified EPR technologies for *"meaningful use"*, to focus on improvements of care (Blumenthal & Tavenner 2010; Slight *et al.*, 2015). This has accelerated the adoption of technologies—in 2003, only 2.7% of

hospitals in the US had CPOE with integrated CDS, compared to approximately 80% in 2015 (Pedersen *et al.*, 2015).

In the UK, the process of implementation has been somewhat slower, with less than a quarter of hospitals in England having CPOE embedded across inpatient wards (McLeod *et al.*, 2014), though questionnaire studies have consistently shown that many more are either in the process of procurement or planning implementation (Ahmed *et al.*, 2013; Cresswell *et al.*, 2013a; Crowe *et al.*, 2010; McLeod *et al.*, 2014). This rate of implementation has particularly increased since 2013, as a result of funding made available to NHS organisations to incentivise the adoption of digital technology. The 'Integrated Digital Care Fund' (formerly referred to as the 'Safer Hospitals, Safer Wards Technology Fund') was established by NHS England in 2013 to *"facilitate the widespread adoption of modern, safe standards of electronic record-keeping"* (NHS England, 2014; NHS England, 2013). A further £4.2 billion was allocated in 2016 to support the digitisation of the NHS (National Information Board, 2014), with the implementation of CPOE one of the main recommendations for hospitals (Wachter, 2016).

1.2.2 Unintended consequences of CPOE

The implementation of new technology into complex systems, such as in healthcare, can have some unintended and often unanticipated consequences. Unintended effects have been defined as those that are "*neither anticipated nor specific to the goals of the associated project*" (Campbell *et al.*, 2006). Some of these may not become immediately apparent, but may evolve as systems become more embedded into the culture of an organisation.

Medication errors caused by staff interacting with the CPOE system—so called 'socio-technical' incidents—have the potential to introduce new risks to patient safety (Barber *et al.*, 2006; Brown *et al.*, 2016; Redwood *et al.*, 2011; Westbrook *et al.*, 2013). Some of these errors are not surprising (and were likely predicted) when you consider the process of prescribing with a pen on paper and then the process on a computer.

CPOE systems contain a dictionary of names of medicines. On starting to generate a prescription order in a computer, most drug dictionaries will create a drop down menu of the medicines that start with the letters typed. This display can lead to 'selection errors', with a potential to generate a prescription for the wrong drug and increase the risk of patient harm (Brown *et al*., 2016; Castro. G. M., 2016). Many systems have complex CDS, which can generate an order in its entirety based on a medicine selected from a drug dictionary (i.e. with the common dose, frequency, route and time auto-populated). In theory this can help ensure an accurate prescription and save some time for the physician. In practice though this can lead to 'default errors', where the proposed order is accepted contrary to that required by the patient (Brown *et al*., 2016; Koppel *et al.*, 2005). There have also been multiple reports of errors occurring in relation to the timing of administration, specifically delays as prescription orders are generated unbeknown to the nurse (Amato *et al.*, 2017). Compared to paper, healthcare professionals are now exposed to active alerts (e.g. warnings) generated by CDS when interacting with a patient's clinical record and prescription profile ('drug chart'). As users are faced with multiple alerts over a period of time, their response to these can fall. The so called "*alert fatigue*" can render CDS less effective than intended, or even ineffective, with the potential to impact on patient safety as

staff are not fully informed of the potential implications of their actions (Khalifa & Zabani, 2016; van der Sijs *et al.*, 2008b; van der Sijs *et al.*, 2010). Finally, there is evidence to suggest that information in CPOE systems can be fragmented, or even hidden, compared to paper processes; user displays may not prompt the access or generation of information or data (Varpio *et al.*, 2015a), which can have an impact on clinical reasoning.

The use of CPOE has also been found to change communication, coordination of work and workflow patterns. The technology can often facilitate remote working, whereby staff depend more on computers to complete their tasks and can access these away from the clinical setting (i.e. the ward). This can have a direct impact on opportunities for personal interaction with patients and colleagues, with the potential to impact on the coordination of care and interprofessional relationships in the longer-term (Taylor *et al.*, 2014). The CPOE system can also lead to breakdowns in communication, where the system—as a modality for medication-related communication—is dependent on the documentation of information by users and access to information already within the system (Saleem *et al.*, 2011), both of which are highly dependent on user display as well as the appropriate training.

Active (interruptive) alerts generated by CDS can impact on the workflow of professionals. Users of the system can be forced to pay attention to the alerts in order to progress through an electronic process (e.g. when adding a new prescription) (Murphy *et al.*, 2012). This can be a particular problem when alerts require immediate attention, which are not directly relevant to the task at hand. Such active alerts can be disruptive to workflow and often lead

to a need to multi-task, which can increase the risk of procedural errors (Laxmisan *et al.*, 2007).

Finally, CPOE systems store user interactions, as well as the data generated on a daily basis. This can be used to drive quality improvement through the ongoing monitoring of safety indicators and using the information to provide feedback to staff. However, this has also been shown to impact on the workflow and workload of staff, since it can encourage users to prioritise or conduct tasks that are monitored (Dixon-Woods *et al.*, 2013), rather than those that require attention.

Research has shown that the unintended effects of CPOE technology can be minimised by ensuring engagement of users during the process of procurement and implementation, appropriate planning and training and local control of how systems are configured to reflect the working environment (Cresswell *et al.*, 2013b).

1.3 Communication in healthcare

Communication is the *"process of submitting information and common understanding from one person to another"* (Keyton, 2010, cited in Lunenburg, 2010). It is a non-technical (social and cognitive) skill that complements clinical skills in healthcare. The process requires a sender and recipient, with information transferred and received. The effectiveness of communication has been shown to depend on the modality used (e.g. face-to-face) and any *"noise"* in the process (Figure 1.1, adapted from Lunenburg, 2010). Noise may include factors such as language barriers, or the frequency of communications, such as with

receiving hundreds of emails on a daily basis. Upon receipt of information, the process of communication is complete when feedback has been provided and received by the sender.

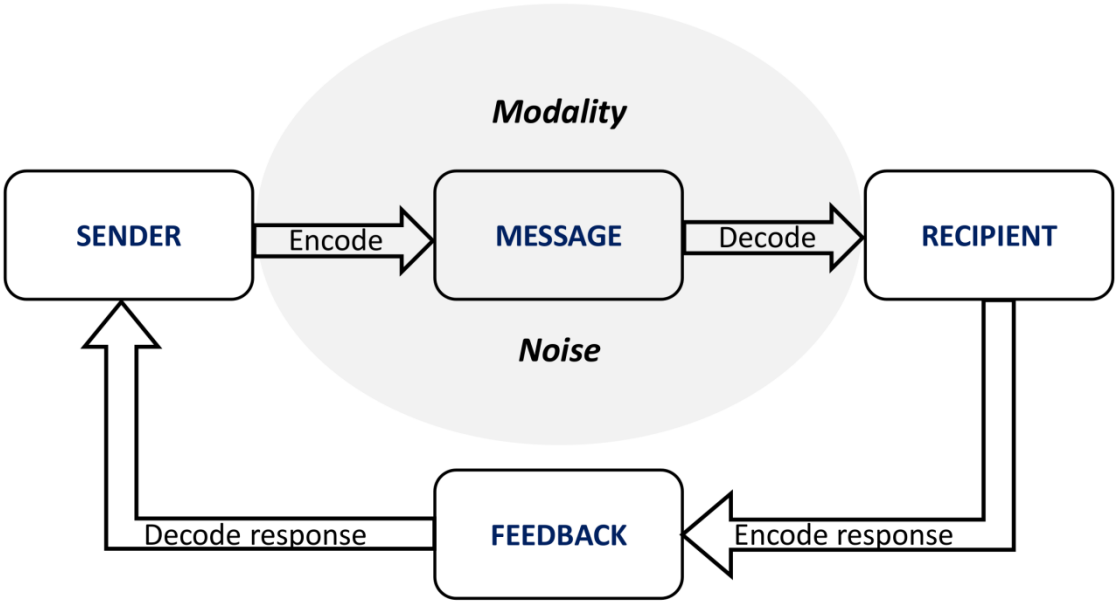


Figure 1.1 – Process of communication

The delivery of safe, effective and seamless care is highly dependent on effective communication between healthcare staff and between staff and patients. In a complex health setting such as a hospital, many people with a range of professional backgrounds will interact with the patient and contribute to their care. In doing so, healthcare professionals will clearly document their encounter and any outcomes or recommendations in the patient's clinical (medical) records. This is a core and essential component of their role and ensures that the wider multidisciplinary team are aware of the actions taken and decisions made by others, which allows for care to be effectively coordinated during an admission. This is never more important than in a health system where patients' clinical records are not integrated across sectors of care, such as in parts of the NHS.

In the hospital setting, healthcare staff rely on a combination of modalities of communication to perform their tasks and coordinate their care. There are many technologies that can facilitate this, including: alphanumeric pagers, Smartphones, mobile phones, hands-free devices and task management systems (Wu *et al.*, 2012). Electronic patient records, such as CPOE, may also provide such a capability, with the ability to send electronic messages to or between staff. All these methods can facilitate *ad-hoc* communication and are especially important for communicating in a setting where staff are likely to be distributed, such as in a hospital. Depending on the modality selected, communication can be synchronous—where two (or more) people participate in a conversation at the same time—or asynchronous, that does not require participants to be present at the same time. Synchronous communication is interactive, but may be interruptive if the exchange is not planned (such as it would be during a handover) (Edwards *et al.*, 2009). In contrast, asynchronous communication provides flexibility for when information is sent and received (i.e. at a time considered convenient for each) (Parker & Coiera, 2000). Studies investigating the satisfaction of professionals using the various modalities of communication highlight the importance of considering workflow and workload during their implementation (Nguyen *et al.*, 2015; Wu *et al.*, 2012). The ability to communicate *ad-hoc* is beneficial, but can lead to interruptions and distractions for the recipient, particularly with mobile devices and Smartphones (Gill *et al.*, 2012). Therefore systems introduced to facilitate, improve, enhance, or replace existing channels of communication should consider the participants of the communication (sender and receiver) and the wider healthcare team.

Despite the array of methods to facilitate the process, poor or ineffective communication remains one of the leading contributing factors of adverse events in healthcare (Ackermann, 1996; Castro. G. M., 2016; Reason, 2004; The Joint Commission on Accreditation of Healthcare Organizations, 2015; Zinn.C, 1995). It is also repeatedly listed as one of the perceived causes of prescribing errors by those directly involved with such incidents (Dean *et al.*, 2002a; Dornan *et al.*, 2009; Ross *et al.*, 2013; Ryan *et al.*, 2013; Tully *et al.*, 2009). As healthcare transactions become more digitised, maintaining effectual communication is a priority for organisations and system developers. In view of the risks associated with breakdowns in communication amongst staff, guidance has been issued in the US so that organisations can assess the safety of their technology in relation to *"Clinician communication" and* take the necessary steps to optimise use (Office of the National Coordinator for Health Information Technology, 2016). Examples of guidance include the ability to assign an urgency to a message and for the status of electronic communications to be visible (e.g. read, acknowledged).

1.3.1 Communication and the medication process

The drug chart is considered the focal point for healthcare professionals to communicate and coordinate necessary and relevant information about the medication process and the patient. The process, traditionally documented on paper drug charts, is gradually being replaced with CPOE (see 1.2.1). In paper-based prescribing environments, research has shown that pharmacists write on or leave notes on drug charts to facilitate nurse administration or "*subtly influence medical prescribing*" to benefit patient care (Liu *et al.*, 2014). In response to any medication-related problems identified, the pharmacist would

communicate with the physician synchronously (e.g. face-to-face discussion or telephone conversation); or asynchronously with written advice in the clinical record or on paper intervention notes attached directly to the drug chart. In the presence of CPOE, the ability to write on the prescriptions is removed, but there is often a function for pharmacists to communicate information electronically, by assigning a message to an individual prescription order or patient profile. In addition to the formal documentation of the activities of the medication process, healthcare professionals interact with one another to seek advice regarding medication. In environments where information seeking networks are limited among staff, the rate of medication errors has been reported to increase (Creswick and Westbrook, 2015). This may highlight the importance of multidisciplinary working and direct interaction to coordinate the process safely and effectively.

The drive to digitise patient records in the NHS will see an increase in the implementation of CPOE systems in the hospital sector. The technology will change the focal point of medication-related communication and coordination, from a paper-based system of drug charts to a single computer interface. This has the potential to change how pharmacists communicate with prescribers, particularly physicians, regarding the optimisation of pharmacological treatment regimens for patients. Since the delivery of safe, effective and seamless care is dependent on effective communication between healthcare staff, it is important that the impact of CPOE on pharmacist-physician communication is investigated. Such research will allow for any unintended effects on the medication process to be identified, which will enable hospitals to adapt their processes accordingly to minimise any potential impact on patient care.

1.4 Aims and objectives

The aim of this research is to understand how the use of CPOE and CDS technologies in the hospital setting have an impact on pharmacist-physician communication. The objectives of the research are to:

1. Determine the effectiveness of uni-directional electronic communications sent via a CPOE system in a large acute hospital and identify factors that may influence this;
2. Ascertain the perceptions of pharmacists and physicians of their interprofessional communication in the context of the technology; and
3. Observe pharmacists' routine clinical work and their professional interactions in the context of the technology.

1.5 Outline of the thesis

The chapters of this thesis are presented as follows:

- Chapter 2: presents the findings of a systematic review of the literature of pharmacist-physician communication in the context of CPOE in the hospital setting. Emerging themes from the review inform the qualitative research described in chapter 8 and the final discussion.
- Chapter 3: presents the findings of a narrative review of studies that examine the incidence and prevalence of medication prescribing errors or drug-related problems in the hospital setting. The findings inform the method used to code the themes of communications described in chapter 5.

- Chapter 4: presents an eDelphi study to identify high-risk prescribing indicators that are relevant to the hospital setting and amenable to CDS. The findings inform the method used to identify and code communications relating to high-risk errors described in chapter 5.
- Chapter 5: presents the methods used to capture and code data relating to pharmacist-physician communications in the CPOE system at the University Hospital Birmingham NHS Foundation Trust.
- Chapter 6: presents the findings of a descriptive analysis of the database of pharmacist-physician communications.
- Chapter 7: presents the findings from a statistical analysis of temporal, prescription and message factors on the sign-off and action of pharmacist-physician communications.
- Chapter 8: presents the findings from qualitative research conducted at University Hospital Birmingham NHS Foundation Trust and Guy's and St Thomas' NHS Foundation Trust.
- Chapter 9: presents a summary of the findings of the research through a process of triangulation and recommendations for system design and workflow that may optimise communication and considers future work.

Chapter 2 A SYSTEMATIC REVIEW OF THE LITERATURE

In this chapter, I describe the methods used to identify relevant studies that examine pharmacist-physician communication in the context of CPOE and CDS in the hospital setting. I categorise the topics that emerged during the review into five key themes and provide a narrative of the main findings. I demonstrate that, at the time of the review in 2012, very few published studies focused on pharmacist-physician communication, highlighting a gap in the research landscape relating to this topic.

A summary of this chapter has been published in the *European Journal of Hospital Pharmacy*: Thomas, S. K. and Coleman, J. J. (2012). The impact of computerised physician order entry with integrated clinical decision support on pharmacist–physician communication in the hospital setting: a systematic review of the literature. *European Journal of Hospital Pharmacy: Science and Practice*, 19 (3): 349-354.

2.1 Background and research question

As new technology is embedded into the culture and organisation of a hospital, unintended and unanticipated consequences can also emerge. In light of this, the implementation of CPOE has the potential to change communication between healthcare professionals who are involved in the medication process. The objective of this study was to determine whether the introduction of CPOE with integrated CDS has an impact on pharmacist-physician communication in the hospital setting and to document any themes identified from the introduction of this technology. Any themes identified will be used to frame the on-going research.

2.2 Method

2.2.1 Methodological approach

A systematic review of the literature can identify quantitative and qualitative studies specific to a defined research question. The methodology adopted can focus the search to consider factors relating to the population (or participants) of interest, any interventions, comparisons, outcomes and the study design (referred to as the PICOS elements) (Cochrane, 2012). In this case, the PICOS elements to search for articles relating to pharmacist-physician communication in the context of CPOE in hospital are as follows:

- Participants: pharmacists and physicians
- Intervention: CPOE and CDS technology
- Comparison: paper-based prescribing processes
- Outcome: communication

- Study design: quantitative or qualitative

2.2.2 Study identification

A search was performed on MEDLINE (1948 to November Week 3 2011, including In-Process & Other Non-Indexed Citations and Daily updates), EMBASE (1947 to November 23 2011) and PubMed.

2.2.3 Search terms

Subject headings, for example Medical Subject Headings or MeSH® terms (U.S. National Library of Medicine, 2011), were identified for each database relating to the elements of PICOS to increase the specificity of the search. The study design was not specified in the search to avoid any restriction. A '$' was used to identify where a word may contain an 's' or 'z' to include articles with US and British English spelling.

- **EMBASE:** [computeri$ed provider order entry (exp); [OR] electronic prescribing (exp); [OR] decision support system; [OR] hospital information system (exp)]; [AND] [interpersonal communication; [OR] interdisciplinary communication] [AND]; [pharmacist; [AND] physician (exp)].
- **MEDLINE / PubMed:** [medical order entry systems (exp) [OR]; electronic prescribing (exp) [OR], drug therapy, computer-assisted (exp) [OR[; decision making, computer assisted (exp) [OR]; hospital information system (exp)]; [AND] [interprofessional relations; [OR] interpersonal relations; [OR] interdisciplinary communication (exp); [OR] communication]; [AND] [pharmacist (exp); [OR] physician (exp)].

The subject headings were exploded to include narrower related terms where appropriate. Where narrower terms were not included under the subject headings, these were added to the search as 'free text'. An 'any field' search was also carried out using the NHS Evidence database.

2.2.4 Inclusion/exclusion criteria

Papers that focused on medication-related communication between pharmacists and physicians in hospital were included in the review. All modalities of communication were included (e.g. face-to-face, phone, written or electronic). The medication process in the hospital site of study was required to be supported by a CPOE system and integrated with CDS. Papers were excluded in the review that focused on CPOE systems in the community setting or at the care interface. Studies that focused solely on communication between other specified healthcare professionals, such as between the nurse and physician, were also excluded. The language and date of publication were not defined.

When studies appeared to meet the inclusion criteria or when a decision could not be made based solely on the title or abstract, full-text copies were obtained. Articles that cited or were cited by the included studies were screened to identify any further relevant studies. In addition, reference lists from important reviews were searched and personal files were examined to identify further studies. The selection process was validated by two independent researchers and the final decision for the articles agreed by consensus.

2.2.5 Review and emerging topics

For each of the studies selected for inclusion, the following data were recorded: the country and year of publication; the electronic system defined; and, pharmacist participation in any qualitative work was highlighted. The content of the articles was analysed in full and categories applied to specific areas of the text that related to the research question (e.g. CDS). After all articles were analysed, the categories were collated and grouped together to allow for a structured narrative review of the studies.

The quality of the studies was also considered during the review, with any discrepancies in the reporting or sources of bias identified. Qualitative studies were assessed for the clarity of their aims and objectives, the appropriateness of the research design, the recruitment of participants (and who they were), the setting and method for data collection, the researchers (who they were and how many), methods for data analysis and finally the reporting of the findings (Mays & Pope, 2000; Spina *et al.*, 2011).

2.3 Results

2.3.1 Summary of the studies

In November 2011, MEDLINE (1948 to November Week 3 2011, including In-Process & Other Non-Indexed Citations and Daily updates), EMBASE (1947 to November 23 2011) and PubMed were searched using the terms described (see 2.2.2). A total of 48 papers were identified, of which 24 were excluded based on the title and abstract. The remaining 24 papers were reviewed in full-text and seven were selected for inclusion (Figure 2.1). Table

2.1 lists the articles identified, the country where the research was conducted, the year of publication and the aims and objectives of each study. The review identified six journal articles and one proceeding paper; of which three were based in the US, three in France and one in the Netherlands. The research methods used were qualitative (n=5), quantitative (n=1) and mixed-methodology (n=1). All studies were conducted in the hospital setting. The focus of the seven publications were: work flow (n=1); communication/ task coordination (n=2); pharmacy alerting and acceptance (n=3); and unintended consequences (n=1).

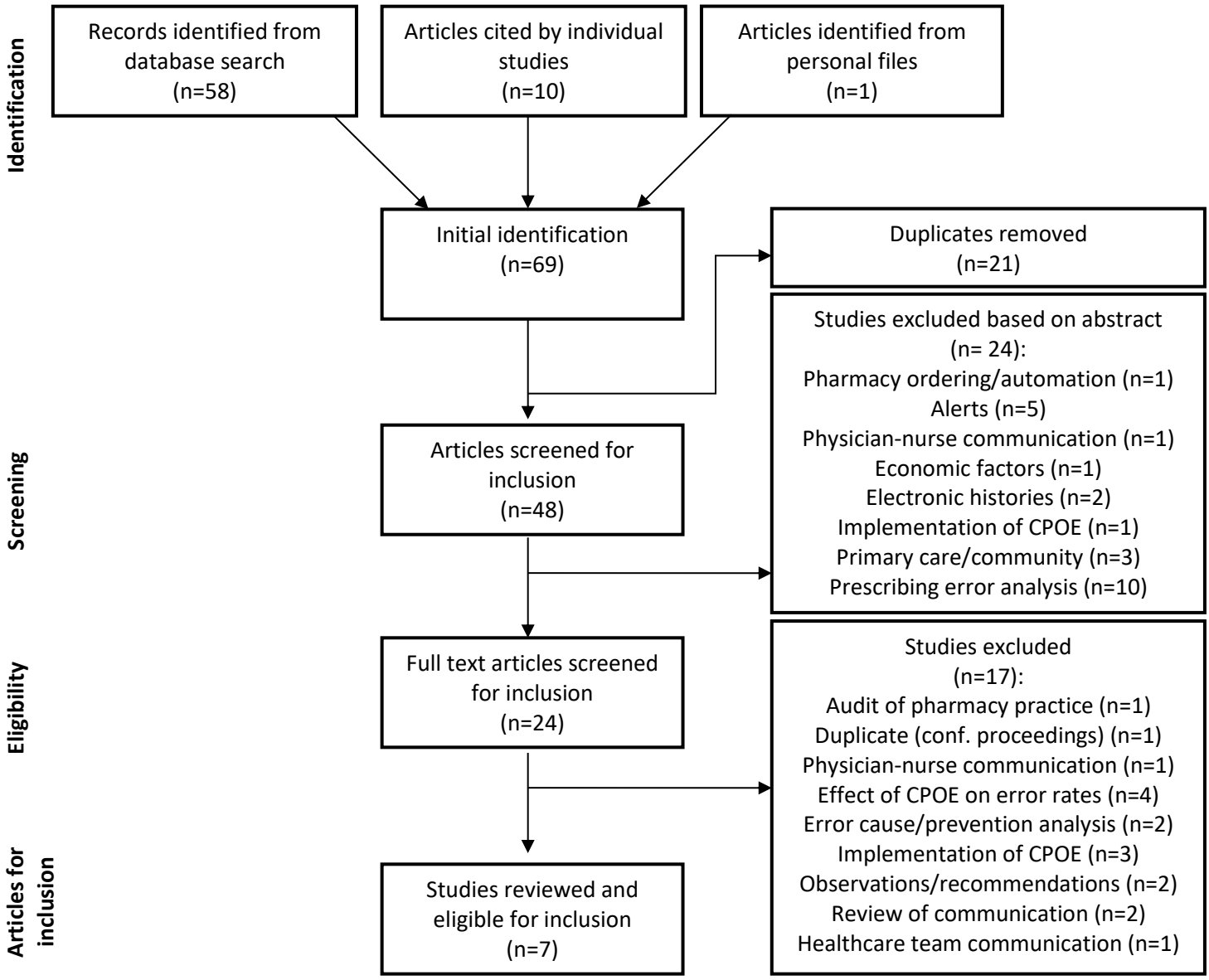


Figure 2.1 – Flow chart for article selection in the systematic review

Table 2.1 – Characteristics of studies identified in the systematic review

Author (year)	Country	Study aim	Study type	CPOE/ CDS system	Study description	Pharmacist participation
(Aarts *et al.*, 2007)	USA	To describe the perceived effects of CPOE on professional collaboration, workflow and quality of care	Qualitative	Not defined	16 semi-structured interviews 17 participatants	One interviewed
(Ash *et al.*, 2004)	USA	To assess the types of medication errors witnessed in hospitals using CPOE and the nature of these errors	Qualitative	Various CPOE systems with integrated CDS	Summarises literature on Patient Care Information Systems (PCIS): 340 hours of observations (USA) 59 formal interviews (USA) 18 semi-structured interviews (Australia)	Three interviewed
(Bedouch *et al.*, 2011)	France	To analyse pharmacists' interventions in a setting where CPOE is in use and a pharmacist works on the ward and the acceptance of these	Quantitative	Cristalnet®	Prospective analysis of pharmacist interventions	Documentation of interventions, validation of categorisation
(Caruba *et al.*, 2010)	France	To describe the prescribing error rate during a patient's stay and the characteristics of the error most predictive of their reproduction the next day despite pharmacists' alerts	Quantitative	Commercially available system DX-Care*	Prospective analysis of 96 pharmacy alerts communicated via CPOE	Data collection

Author (year)	Country	Study aim	Study type	CPOE/ CDS system	Study description	Pharmacist participation
(Dykstra, 2002)	USA	To examine how CPOE alters the full range of communication within institutions and how communication influences the success of CPOE	Qualitative	Not directly defined	Retrospective re-examination of qualitative data	Not directly defined
(Estellat *et al.*, 2007)	France	To describe pharmacists' interventions via CPOE, their impact and the extent CPOE is responsible for medication errors	Mixed - methods	Commercially available system DX-Care, Medasys™	Prospective analysis of 81 pharmacy alerts communicated via CPOE 48 semi-structured interviews with targeted physicians	Data collection, independent review and validation of error and interviewer
(Niazkhani *et al.*, 2010)	The Netherlands	To assess the effects of a CPOE system on interprofessional work flow in the medication process	Qualitative	Commercially available system Medicatie/EVS	23 semi-structured interviews	Two pharmacists and One pharmacy technician interviewed

*Medasys, Gif sur Yvette Cedex.
†Leiden, The Netherlands.

2.3.2 Narrative review of included studies

Several topics emerged during the analysis of the seven studies, which were grouped to illustrate the potential impact of CPOE and CDS on pharmacist-physician communication: computer entry: a false communication; interpersonal communication; the impact of pharmacist messages in an electronic format; physician accessibility to pharmacist alerts; and the effect of CDS on communication.

2.3.2.1 Computer entry: "a false communication"

Communication in the context of CPOE is largely one-way—where the person-computer interaction is one that is uni-directional. This was found to impact on the effectiveness of communication, as well as the coordination of work between healthcare professionals (Ash *et al.*, 2004; Dykstra, 2002). Initiating a communication via the computer was found to give a *"false sense"* (Dykstra, 2002) that a communication had been completed, with the information transferred effectively and received as intended. This was compared to communications that were written, which were more likely to be followed up with direct communication as there was more of a sense that *"it hasn't gone anywhere"* (Dykstra, 2002). The assumption that a communication had been completed via the computer was found to increase the risk of miscommunication regarding management plans (Ash *et al.*, 2004), particularly because further action may not be taken to ensure the information had been received.

Ash *et al* (2004) describes how communication in healthcare is conducted to generate an *"effect"* and that it is not just about the transfer of information, but also the "*testing of assumptions regarding the other person's understanding of the situation and willingness to*

act on the information". Effective two-way communication is vital in healthcare and for the medication process to run efficiently. The authors concluded that two-way communication could be beneficial since it can provide flexibility in the system—needed to better fit real working practices—and that feedback mechanisms are needed so that professionals can better coordinate tasks and maintain an awareness of the steps of the medication process (Ash *et al.*, 2004).

2.3.2.2 Interpersonal communication

The increased interaction with the computer and false sense that a communication has taken place, has the potential to reduce interpersonal communications (Ash *et al.*, 2004). CPOE systems also facilitate remote working where physicians can generate prescription orders from any location and simultaneously review patient records that are being used by another healthcare professional. This capability can reduce the opportunities for direct interaction with other healthcare professionals working on the ward; "*One of the complaints we've heard is that there's not that physical presence; that people aren't around as much to ask questions and to get this interaction with*"(Dykstra, 2002). In one qualitative study, although CPOE was found to be beneficial for physician–pharmacy workflow, interpersonal communications were reported to increase (Niazkhani *et al.*, 2010). This was as a result of needing to perform extra tasks to coordinate work, such as with writing paper notes and initiating phone calls and face-to-face communication. A second qualitative study investigating the perceived effects of CPOE on professional collaboration, workflow and quality of care reported that none of the professional groups involved in the medication process (physician, nurse and pharmacist) relied on the system to coordinate tasks (Aarts *et*

al., 2007). Other modalities of communication were used by staff to coordinate inter-dependent tasks.

2.3.2.3 The impact of pharmacist messages in an electronic format

Two studies in France investigated pharmacy messages that were targeted at physicians and sent via the CPOE system and the impact of these on the medication process. The first study aimed to identify the types of interventions communicated and their impact on the prescribing process (Estellat *et al.*, 2007). The second to identify the characteristics of a prescribing error most predictive of their reproduction the next day (i.e. messages being overridden) (Caruba *et al.*, 2010). In both studies, the pharmacist could validate orders on the CPOE system with *"accepted (agrees)"* or *"refused (disagrees)"* symbols inserted next to the order line, as well as communicate messages (or "*alerts*") electronically in response to a prescribing error. Both studies reported a low acceptance rate of pharmacists' alerts that were communicated via the CPOE system. In the first of the two studies, pharmacists did not participate in ward rounds and provided advice to the physician only via the CPOE system (Estellat *et al.*, 2007). Out of the 81 alerts analysed, only 26% (n=21) resulted in a modification of therapy. When physicians were asked why they had not accepted the pharmacy alert (i.e. modified the prescription) the most common response suggested that the physician did not agree with the pharmacist's recommendation; "*I think my order is clear enough for the nurse"* (24%) and *"due to disease progression, biology, or a specific context, it wasn't required"* (22%). The authors proposed that the impact of pharmacists' interventions were questionable owing to the high number of prescriptions that were not modified. In the second study, the pharmacist visited wards to review electronic

prescription orders on Monday to Friday (Caruba *et al.*, 2010). A total of 96 alerts posted by pharmacists to physicians were analysed and 48% (n=46) resulted in an amendment of the prescription. The authors rationalised the low level of acceptance because clinical pharmacy was a relatively new and expanding concept in France and despite the low acceptance, concluded that implementation of electronic alerts to communicate medication-related issues to the physician "*could complement the pharmacists' validation tasks and make the prevention of prescribing errors more efficient"* (Caruba et al., 2010).

Physician acceptance of pharmacists' advice was investigated prospectively in a French teaching hospital (Bedouch *et al.*, 2011), specifically investigating factors most predictive of acceptance. In this study, 86.6% of assessable interventions were accepted by physicians. Slightly more interventions were communicated electronically via the CPOE system (n=257/448, 57.4%) compared to verbally. The modality of communication was found to significantly affect the time to acceptance of requests ($p<0.001$); with the majority of interventions communicated verbally accepted by the physician within one hour. The study found oral communication to be a predictive factor of intervention acceptance.

2.3.2.4 Physician accessibility to pharmacy alerts

The accessibility of pharmacist messages ("*alerts*") communicated via a CPOE was identified as an issue in two studies investigating the impact of such messages on the medication process. In one, a total of five clicks were reported to be required in the CPOE system for the physician to access and read the message (Caruba *et al.*, 2010). In a similar study where the reasons for physicians' non-adherence with pharmacy alerts was investigated (Estellat *et al.*, 2007), the third most common response was "*It's an omission, I haven't seen it yet*"

(16% (n=8/49)). Other explanations included: "*I did not know how to view the text comment of the pharmacy alert"* (8% (n=4/49)) and "*the prescription was difficult to modify with the software*" (10% (n=5/49)). The authors recommended that display characteristics were important and *"ergonomic improvements"* (Estellat *et al.*, 2007) were needed to ensure communications were more accessible.

2.3.2.5 Clinical decision support: effect on communication

The advanced functionality of CDS systems can, for example, allow the physician to review the medicines that are available (in stock) for prescribing within the hospital. In a qualitative study investigating the effects of CPOE on interprofessional workflow in the medication process, access to CDS was found to decrease the number of interruptions for the physician from someone in pharmacy calling to discuss an alternative medicine rather than one that was unavailable (Niazkhani *et al.*, 2010). The system enabled physicians to enter a reason for their prescription order, therefore communicating a rationale to the pharmacist (or other healthcare professional) and preventing the need for a call to be made for clarification. Fewer call-backs were also made to physicians for illegible or incomplete prescriptions in the study.

A second study investigating the perceived impact of CPOE on professional collaboration, workflow and quality of care (Aarts *et al.*, 2007), highlighted a pharmacist's perceptions of CDS and how this might impact on their on the role. The pharmacist communicated an understanding that some CDS functionality will replace the requirement for their interventions to be made as the system may detect many of the errors and alert the

physician instead. As a result, contact with the physician may not be required to such an extent. On the other hand, the same pharmacist stated that the role of the pharmacist may shift and "*might become broader*", with a potential of increasing collaborative working. This was supported by Estellat *et al* (2007), the authors of whom concluded that the development of further CDS, such as for drug-dose adjustment and availability of medicines, may prevent some prescribing errors and would enable pharmacists to "*concentrate on the most relevant interventions"* when reviewing and validating prescriptions (Estellat *et al.*, 2007).

2.3.3 Study and reporting quality

In this review, two of the three studies incorporating quantitative analysis of pharmacy alerts (Caruba *et al.*, 2010; Estellat *et al.*, 2007) had a low sample size (n=81 and 96 alerts respectively) collected over a short period of time, with an inevitable impact on the power of the study. In one of these, the physicians' reasons for not adhering with the pharmacists' alerts were investigated using semi-structured interviews (Estellat *et al.*, 2007). The method adopted was the use of a multiple choice form with four possible reasons and a fifth reason as 'other' allowing for a free-text comment. This gave the interviewee less scope to express their opinion or feeling on the subject and may inadvertently direct them to select an option that could remove accountability. The third quantitative study examined a comparatively larger number of pharmacist interventions (n=448) and looked at the factors most predictive of their acceptance, such as the modality of communication used (Bedouch *et al.*, 2011). In this study, on-ward integration of clinical pharmacists occurred at the same time as CPOE implementation. As a result, the significance reported between electronic and

verbal communications with regards to physician acceptance may have been influenced by the recent pharmacy service provided at a ward level. In the four qualitative studies comprising interviews, pharmacist participation was low (see Table 2.1). One study recruited only one pharmacist, who was also the project lead for the CPOE implementation (Aarts *et al.*, 2007). This introduces a potential for bias compared to other participants, though this was not evident from the article. In this same study, the recruitment of participants was made via an invitational consensus meeting, which may also introduce an element of bias. This was acknowledged by the authors as a limitation, but it was also expressed that the risk was minimised owing to the variety of professional backgrounds. In three studies, the methods for participant recruitment were not stated (Ash *et al.*, 2004; Dykstra, 2002; Niazkhani *et al.*, 2010). One study re-examined data initially gathered in qualitative research looking into how CPOE alters the full range of communication within institutions and how communication influences its success (Dykstra, 2002). The retrospective review was carried out by the author of the article, who was not named as a contributor in the original study (Ash *et al.*, 1999). When quotes were provided within the text, the profession or grade of the interviewee was not defined and occasionally, who they were referring to was not stated.

2.4 Discussion

In this review, I aimed to explore the impact of CPOE with integrated CDS on pharmacist-physician communication in the hospital setting. The review identified seven relevant studies, the small number of which demonstrates a gap in the research and knowledge relating to this subject. Out of those studies included, several topics emerged that were

categorised to allow for a narrative review of the findings: computer entry: "*a false communication"*; interpersonal communication; the impact of pharmacist messages in an electronic format; physician accessibility to pharmacist alerts; and, the effect of clinical decision support on communication.

This review highlighted how personal interactions can be reduced in a setting that utilises CPOE and CDS in one of two ways. First, health technology such as CPOE can facilitate a workflow whereby the presence of healthcare professionals in the same space as each other, such as on the ward—is no longer necessary to carry out medication-related tasks. Second a reduction in the frequency of communications between the pharmacist and the physician as a direct result of the technology.

Personal presence was found to change for two reasons. First, an interaction with the computer to complete or review steps of the medication process can create a sense (and therefore assumption) that a communication has occurred with other members of the multidisciplinary team. In the case of a pharmacist communicating an intervention via the CPOE system, submission of a message via the computer may lead to an assumption that the task has been completed and that a personal interaction with the physician is no longer necessary to follow-up or coordinate the task. Second, the ability to interface with the computer from any location means that healthcare professionals do not need to be present in the same vicinity (e.g. on a ward) to carry out medication-related tasks and documentation. Physicians can enter medication orders and pharmacists validate and review these orders at a distance from one another, which can reduce the opportunity for personal interactions, whether formal or informal in nature. Evidence suggests that this

increased reliance on the computer to complete tasks and communicate can have an impact on the coordination of work between physicians and nurses (Beuscart-Zephir *et al.*, 2005; Pirnejad *et al.*, 2009; Pirnejad *et al.*, 2008), which has the potential to increase the risk of miscommunication, with potential for error. It is important that organisations and staff are aware of the potential for this unintended effect of the technology and put processes in place to account for this prior to implementation. This may include the consideration of system design and choosing a system that provides the capability to allow healthcare professionals to more effectively coordinate their work within the system (e.g. two-way communication), as well as the provision of training to highlight the negative impacts.

The frequency of interpersonal interactions between the pharmacist and the physician was reported to be reduced in the context of CPOE. The technology has the capability to prevent certain medication errors (e.g. caused by illegible orders) and CDS can provide physicians with the information and guidance to support their prescribing, such as with the provision of formularies or protocols. In both cases, CPOE and CDS can serve to replace many of the interventions formerly documented and communicated by pharmacists during the process of clinical check and medication review. As systems provide more complex pharmacological information to guide the prescribing process, the number of encounters between the two professionals may fall. In view of the fact that members of the healthcare team may also become more spatially distributed throughout the hospital, the physician may rely more on the computer for this guidance over time.

Verbal communication was found to increase the acceptance rate of medication-related interventions—predictive of requests being translated into practice. Taking this into

account, a shift towards a virtual modality of communication between the two professions may impact on the integration of pharmacists' work within the clinical team, the physicians' perception of their role and overall acceptance of their clinical interventions. It is important that the potential barriers and disruptions to the flow of information between the pharmacist and physician are highlighted to staff (Georgiou *et al.*, 2007) and that communication functions within systems are designed so that the intended recipient can easily access the information and increase the likelihood that it will be considered and actioned in practice.

Effective communication between the pharmacist and physician could enhance coordinated exchange of information and more immediate resolution of drug-related problems and medication errors. Optimising this exchange in the context of CPOE could increase collaborative working, which can benefit patient care.

2.4.1 Limitations

The topics identified in this review are limited by the small number of studies focusing on pharmacist-physician communication and collaborative work in the hospital setting. Furthermore, the primary aims of the studies included were not to determine the effect of CPOE or CDS on pharmacist-physician communication, but to investigate interprofessional collaboration and workflow generally, or the impact of pharmacist messages in such settings.

2.5 Conclusions

At the time of this review, few studies were identified that investigated how CPOE and CDS impacts on pharmacist-physician communication in the hospital setting. Furthermore, no studies were identified that examined specifically how CDS impacts on what is communicated by pharmacists. Taking the time to examine this relationship in the context of new technologies will allow for a better understanding about the interaction between the professionals and whether this has the potential to impact on the care of the patient. Such an insight may enable channels of communication in existing CPOE systems to be enhanced so that interprofessional work can be optimised to benefit patient care. The themes identified in this review will be used to frame parts of the qualitative research.

Chapter 3 CLASSIFYING ERRORS IN THE MEDICATION PROCESS: A NARRATIVE REVIEW OF THE METHODS ADOPTED IN THE HOSPITAL SETTING

In this chapter, I describe the methods used to identify relevant studies that examine the incidence and prevalence of medication prescribing errors or drug-related problems in the hospital setting. I examine the classification schemes adopted by researchers to categorise errors and identify whether the schemes have been through a process of validation. I demonstrate that at the time of the review, there was no standard approach for classifying medication errors or drug-related problems, despite some published and validated schemes being available. I conclude that developing a classification scheme that is tailored to the research question and local study environment is common practice.

3.1 Background and research questions

Analysing and monitoring the incidence, prevalence and potential cause of errors in healthcare is an essential component of patient safety. The data can be incredibly powerful to an organisation when used appropriately—that is through the sharing of the information,

implementing change to minimise risks and optimise care and then re-examining the impact of that change. The data could be even more powerful if the results of individual studies in a setting (e.g. hospital) could be combined to provide a national rate of error and if settings could be directly compared to one another to drive quality improvement. The collation of such data would require organisations and authors of studies to adopt the same definitions of error, data collection techniques and classification schemes to categorise error types and severity (American Society of Hospital Pharmacists (ASHP), 1993; Franklin *et al.*, 2010; Shawahna *et al.*, 2011; World Health Organization, 2009).

3.1.1 Terminology

Drug-Related Problem (DRP); medication error; medication-related error; and Adverse Drug Events (ADE) are all referred to in the literature when referring to errors occurring during the medication process. The terminology used often changes depending on the aims of the research and potentially who is conducting the study. Furthermore, the definitions for these terms vary in the published literature.

A DRP has been defined as *"A circumstance that involves a patient's drug treatment that actually, or potentially, interferes with the achievement of an optimal outcome" (Johnson & Bootman, 1995)*; a definition that has been adopted (albeit slightly modified) by the Pharmaceutical Care Network Europe (PCNE) Working Group on drug-related problems (Pharmaceutical Care Network Europe, 2012). The definition has been criticised by some since the premise of the DRP is that there is a potential for harm, omitting other problems that may not necessarily pose a risk to the patient (van Mil, 2005). This has led to sub-

categorisation of the term when classifying problems to identify those that involve error and those that do not (Fijn *et al.*, 2002; van den Bemt *et al.*, 2000).

Medication errors have been defined as *"a failure in the treatment process that leads to, or has the potential to lead to, harm to the patient"* (Ferner & Aronson, 2000)—a definition adopted by both the European Medicines Agency (European Medicines Agency, 2014) and the World Health Organization (World Health Organization, 2014). In the US, the National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP) use the definition of *"any preventable event that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of the health care professional, patient, or consumer*" (National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP), 2012). Both definitions make it clear that errors can occur at all stages of the medication process (e.g. prescribing, dispensing) and unlike DRPs, the latter of the two definitions emphasises that the error does not need to lead to patient harm (or potential for harm) as an outcome and that error can simply relate to the use of a medicine.

Attempts have been made to standardise the definition of a prescribing error in the medication process. A practitioner led definition was agreed by consensus as: "*a clinically meaningful prescribing error occurs when, as a result of a prescribing decision or prescription writing process, there is an unintentional significant (1) reduction in the probability of treatment being timely and effective or (2) increase in the risk of harm when compared with generally accepted practice*" (Dean *et al.*, 2000). Despite the publication of this definition, a systematic review conducted nine years later, in which 70% of the studies were conducted

after the definition was agreed, still found that the majority of studies developed their own definitions or modified existing ones (Dornan *et al.*, 2009).

3.1.2 Classification schemes

Classification schemes allow for data and information to be organised using a standard approach and hopefully in a way that can avoid subjectivity in the process. The WHO emphasises the importance of a single classification scheme for monitoring patient safety incidents, since the ongoing use of different taxonomies prevents effective sharing of data, which has a direct impact on learning opportunities (World Health Organization, 2012). A single taxonomy is adopted in the UK, where the NRLS receive patient safety incident reports via a national online database. The use of a single taxonomy to describe incidents within the database means that the information can be analysed on a national level to ascertain where risks exist and identify vulnerabilities in systems that may be contributing to patient harms.

Attempts have been made to standardise the classification of DRPs or medication errors for research and audit purposes (Hohmann *et al.*, 2012; National Coordinating Council for Medication Error Reporting Prevention, 1998; Pharmaceutical Care Network Europe Foundation, 2010). Yet, evidence would suggest that many organisations and researchers continue to use their own schemes to meet local objectives for data collection (Dornan *et al.*, 2009; Schaefer, 2002). Eight principles have been published to facilitate the development of coding systems for DRPs (Schaefer, 2002), but a literature search conducted a couple of years later found that no system met all eight principles (van Mil *et al.*, 2004) and few classification systems had been through a process of validation for their usability.

The aim of this study is to identify how medication errors and DRPs are classified in studies investigating their incidence and prevalence. This will capture information provided by the authors on for the use of schemes to categorise errors and whether these have been through a process of validation. The results of this review will inform the methodology for the categorisation of pharmacist-physician communications in the hospital setting.

3.2 Method

3.2.1 Methodological approach

A systematic review of the literature was selected to identify studies specific to the research question. The PICOS elements relating to the incidence and prevalence of medication errors and DRPs are as follows:

- Population: hospital or secondary care
- Comparison: medication errors or DRPs
- Outcome: incidence or prevalence of medication errors or DRPs
- Study design: retrospective and prospective studies

An intervention was not specified in the search to avoid any restrictions relating to the research methods adopted by the authors in the studies.

3.2.2 Study identification

A search was performed on MEDLINE (1980 to week 9 2012), including In-Process & Other Non-Indexed Citations and Daily updates) and EMBASE (1980 to week 9 2012).

3.2.3 Search terms

Subject headings were identified relating to each of the PICOS elements and for each database to increase the specificity of the search. The subject headings were exploded to include narrower related terms where appropriate: medication error (exp) OR drug related problem; retrospective studies (exp) OR prospective studies (exp); AND incidence (exp) OR prevalence (exp); AND hospital (exp) OR secondary care.

3.2.4 Inclusion/exclusion criteria

Studies published in English were included in the review that focused on the incidence of medication-related error in the hospital setting relating to prescribing. Studies were excluded if they were carried out in the community, ambulatory care or outpatient settings and where only one error type (e.g. dose omissions) or one class of medicine was being investigated. Studies were also excluded if the article did not define the categories within the classification scheme (or make this available as supplementary information online). In cases where studies appeared to meet the inclusion criteria, or where a decision could not be made based on the title or abstract alone, full-text copies were obtained. Articles that cited or were cited by the included studies were screened to identify any further relevant studies not already captured in the search. In addition, the references from reviews were searched.

3.2.5 Review and emerging topics

For each of the studies selected for inclusion, the following data were recorded: country and year of the publication, the aim of the study, the system used in the medication process (i.e. paper-based or computerised) and the terminology for error referred to. For each study,

the categories (and any sub-categories) used to classify the errors were summarised and tabulated. Where a classification scheme was referenced by a study, this was further investigated to examine validation processes to establish whether pre-determined specifications were met.

3.3 Results

3.3.1 Summary of the studies

A total of 122 studies were identified, of which 71 were excluded based on the title and abstract. The remaining 51 papers were reviewed in full-text and 31 of these were selected for inclusion (Figure 3.1).

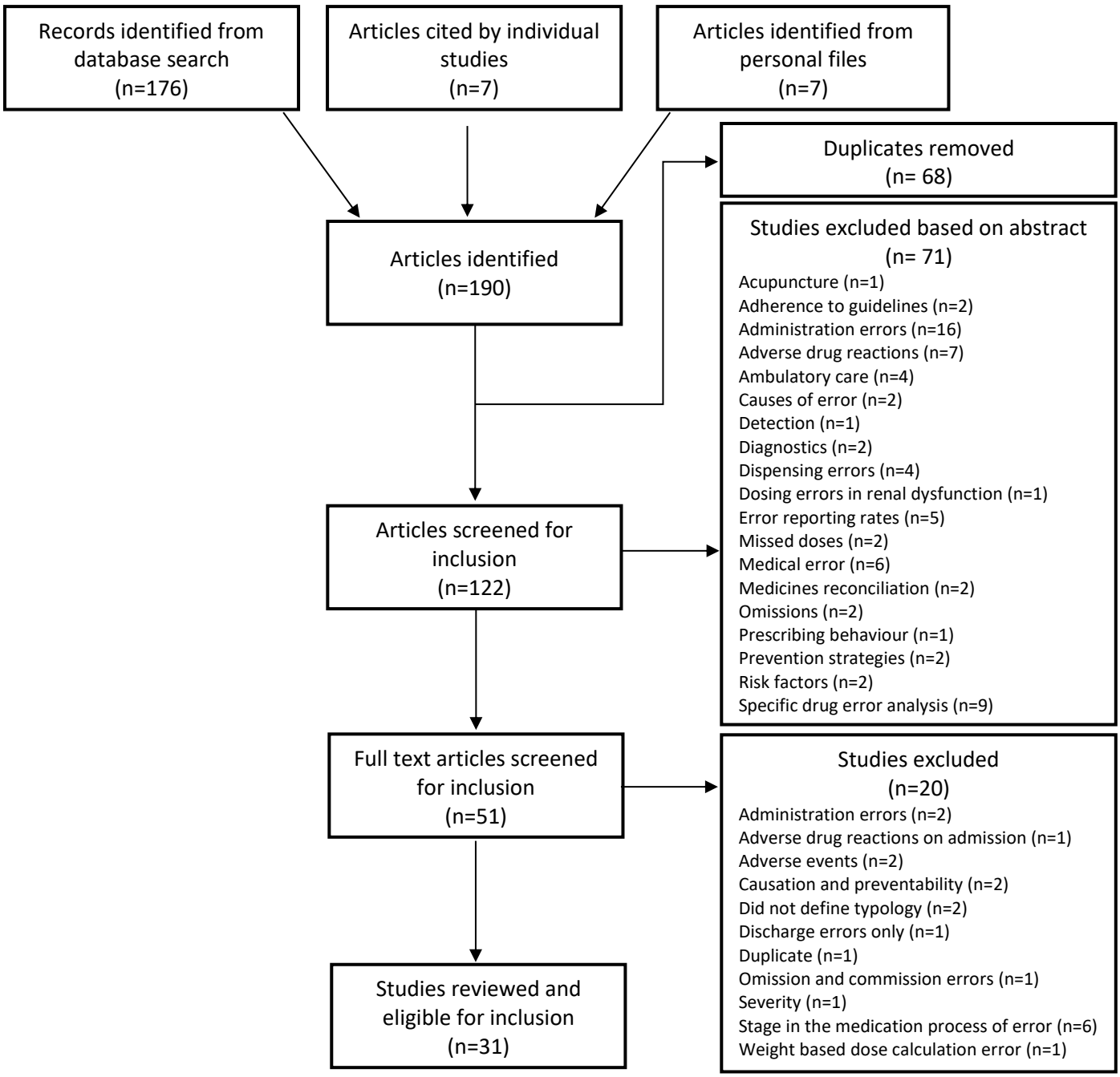


Figure 3.1 – Flow chart for article selection for the narrative review

3.3.2 Narrative review of the included studies

A summary of the 31 studies included in the review is provided in Appendix 1. The studies were conducted in 15 countries, with a high proportion carried out in the US (n=9/31) and UK (n=7/31). The methods used for data capture were prospective (n=18/31) and retrospective analysis (n=13/31) and comprised reviews of medication orders (n=21/31), case notes (n=3/31) and voluntary incident reporting forms alone or in combination with medication order review (n=7/31). The terminology used to describe the errors being investigated ranged, with the majority referring to medication errors (n=16/31) and prescribing errors (n=8/31) and some adverse drug events (n=3/31) and DRPs (n=1/31). There were also studies that used a combination of terms (n=3/31). A CPOE system was used in eight of the study sites, two of which were pre-/post-intervention studies following implementation of the technology. One national study in the US reported on error rates for 496 hospitals, of which 25% utilised some form of CPOE (Pham *et al.*, 2011).

The categories used to classify errors varied widely between studies. The number of potential categories in a single classification scheme ranged from four (Fijn *et al.*, 2002; Vrca *et al.*, 2005) to 20 (Devine *et al.*, 2007) (Table 3.1). Ten out of the 31 studies used sub-categories to further describe the errors. The main category of 'Dose' was used in all the studies, although this ranged from a single statement of 'Wrong dose', to one study separately categorising 'Underdose', 'Overdose', 'No maximum dose stated' and 'Missing dose information' (Dornan *et al.*, 2009). There were categories not mentioned in any other study, for example: 'Not meeting the Beers criteria' and 'CPOE-related errors' (Devine *et al.*, 2007).

Table 3.1 – Summary of the categories used in the studies to classify drug-related problems or medication errors

Author (year)	Patient	Drug	Dose	Form	Route	Timing	Frequency	Infusion rate	Interaction	Contra-indication	Allergy	Monitoring	Duplicate	Omission	Other	Example of additional category	No. of categories	No. of sub-categories
(Lesar *et al.*, 1997b)	■	■	■	■	■						■		■			Underdose	9	0
(Wilson *et al.*, 1998)			■				■	■	■					■	■	Transcription error	9	0
(Ross *et al.*, 2000)	■	■	■		■			■						■	■	Incorrect intravenous concentration	11	0
(Fijn *et al.*, 2002)	■	■	■	■	■		■	■	■	■	■		■	■		Non-existing dosage form	7	29
(Kozer *et al.*, 2002)		■	■		■		■								■	Information	6	0
(LaPointe & G., 2003)	■	■	■	■					■		■			■		Wrong dose or drug	8	0
(Parthasarathi *et al.*, 2003)			■	■					■	■	■	■	■	■		Drug-disease interaction	8	27
(Bobb *et al.*, 2004)			■		■		■	■	■		■		■	■		Drug-food interaction	16	0
(Chen *et al.*, 2004)	■	■	■		■	■								■	■	Out of stock	12	0
(Nebeker *et al.*, 2005)	■	■	■		■	■	■	■	■	■	■	■	■	■	■	Wrong strength/ concentration	14	16
(Vrca *et al.*, 2005)			■				■		■				■				4	0
(Barber *et al.*, 2006)	■	■	■	■	■	■		■					■			Wrong diluent	12	
(Ashcroft & Cooke, 2006)	■	■	■	■		■	■		■					■	■	Wrong strength	15	0
(Colpaert *et al.*, 2006)	■	■	■		■	■	■	■	■	■	■	■	■	■	■	Wrong duration	14	16
(Devine *et al.*, 2007)	■	■	■	■	■			■	■	■	■	■	■			Not meeting Beers criteria	20	17

Author (year)	Patient	Drug	Dose	Form	Route	Timing	Frequency	Infusion rate	Interaction	Contra-indication	Allergy	Monitoring	Duplicate	Omission	Other	Example of additional category	No. of categories	No. of sub-categories
(Jayawardena *et al.*, 2007)			■								■		■			Dose inappropriate for creatinine clearance	8	0
(Marcin *et al.*, 2007)			■	■	■				■	■	■				■		11	2
(Madegowda *et al.*, 2007)	■	■	■		■	■	■	■			■			■		Pre-op medication not re-started	13	0
(Engum & Breckler, 2008)	■	■	■	■	■		■	■			■		■	■			10	0
(Picone *et al.*, 2008)	■	■	■		■	■				■			■	■	■	Adverse effect	11	0
(Kunac & Reith, 2008)	■	■	■		■	■	■	■	■	■	■	■	■	■	■	Monitoring error	14	16
(Pham *et al.*, 2011)	■		■	■	■	■								■		Unauthorized drug given	9	0
(Dornan *et al.*, 2009)			■	■	■			■	■	■	■		■	■		Continuation after adverse drug reaction	29	0
(Ghaleb *et al.*, 2010)			■		■		■	■							■	Use of abbreviations	8	0
(Klopotowska *et al.*, 2010)		■	■	■	■		■					■		■	■	Unnecessary drug use	9	0
(Al-Jeraisy *et al.*, 2011)		■	■		■		■						■		■	Undecided route	8	11
(Franklin *et al.*, 2011)		■	■	■	■						■		■	■	■	No indication	14	0
(Hartel *et al.*, 2011)	■		■			■	■									Wrongly transcribed	3	15
(Jennane *et al.*, 2011)			■		■		■					■		■		Drug not prescribed despite indication	6	0
(Shawahna *et al.*, 2011)		■	■							■				■		Maximum dose not specified on when required	9	9
(Westbrook *et al.*, 2012)	■	■	■	■	■	■	■		■		■	■	■			Not indicated	17	0

A total of 12 articles referred to other published studies to inform the classification scheme (Appendix 1). Four studies adopted the use of the NCC MERP Taxonomy of Medication Errors, either in full (Colpaert *et al.*, 2006; Kunac & Reith, 2008) or as a modified version of this (Marcin *et al.*, 2007; Pham *et al.*, 2011); two used a scheme developed by the author(s) in a previous study (Ghaleb *et al.*, 2010; Shawahna *et al.*, 2011); one referenced the American Society of Hospital Pharmacists (Wilson *et al.*, 1998); one the ADE Prevention Study Group (LaPointe & G., 2003); and four a scheme adopted by other published studies (Barber *et al.*, 2006; Fijn *et al.*, 2002; Hartel *et al.*, 2011; Kozer *et al.*, 2002). One of these published studies referenced a further study for its scheme (Cousins & Hatoum, 1991). Overall nine different schemes were identified, of which three had been through a process of formal validation according to the primary author(s) (Ghaleb *et al.*, 2005; Pharmaceutical Care Network Europe, 2012; Shawahna & Rahman, 2009). A Delphi technique was used by two studies to validate the scheme classification and one was validated during a working conference, although the methodology was not described (Pharmaceutical Care Network Europe, 2012)

3.4 Discussion

In this review I identified 31 studies investigating the prevalence, type and in some instances, the severity of errors in the medication process in the hospital setting. The terminology for error, the methods for data collection and the classification scheme to categorise error types were found to vary widely.

The terminology referred in the studies did not appear to inform the number and type of categories used in the classification schemes. For example, Dornan *et al* (2009) investigated prescribing error and used a classification scheme with 29 main categories, whilst another study only used four (Vrca *et al.*, 2005). Fijn *et al* (2002) investigated prescribing errors, but included categories in the classification scheme such as 'sound-alike drug prescribed' and 'abbreviations for frequency/route'—categories that would not be considered prescribing errors by some practitioner led definitions (Dean *et al.*, 2000). These findings were consistent with previous research that found the definitions for prescribing error were often developed specifically for the study or were modified from existing ones (Bjorkman *et al.*, 2008; Dornan *et al.*, 2009; Lisby *et al.*, 2010).

Despite published classification schemes being available in the literature, the majority of authors of studies did not refer to these as a reference for their method of data analysis. This may suggest that organisations prefer to collect data specific to the study environment and research question and that published schemes do not always fulfil these requirements. It is also important to note that organisations are likely to want to continue to use schemes that they have previously adopted so that direct comparisons can continue to be made for longitudinal analysis of error rates. In those studies that did refer to a published classification scheme as evidence for the method, no authors provided a rationale for their choice. Few of these had been through a process of validation, which is important for testing the accuracy and reliability of a method. This may suggest that this is not always considered an important factor, perhaps because researchers will standardise how they categorise errors with the provision of training to ensure this is approached consistently and internal validation may take place for a proportion of these.

The categories selected to organise data within a scheme were found to vary widely, with some authors adopting very broad descriptions and others more detailed and often presented as sub-categories. The more detailed the description of an error is, the more information that can be captured about the nuances of that error. However, this needs to be balanced against continuing to ensure ease of use of the scheme and avoiding potential confusion between categories (Schaefer, 2002; World Health Organization, 2012).

The use of a CPOE system can reduce the rate of medication prescribing errors, eliminating those associated with illegibility and incomplete information (Barber *et al.*, 2006; Bates *et al.*, 1998; Bates *et al.*, 1999). In this review, few studies were carried out in settings utilising CPOE, but in those that were, the classification schemes were not adapted to account for the new process of prescribing. Two studies referenced a scheme that was developed for paper-based processes (Barber *et al.*, 2006; Shawahna *et al.*, 2011). This may suggest that errors did not emerge in the studies that were believed to be solely related the use of the technology (e.g. selection errors), or did not occur at a rate that would warrant a new category to be added to a scheme.

3.4.1 Limitations

A defined search strategy was used in this review to identify relevant studies, which may not have captured every published study investigating medication errors or DRPs occurring in the medication process. Furthermore, only articles published in English were included and the grey literature was not searched for similar studies. However, I have no reason to believe that a much more comprehensive search strategy would have altered the

conclusions about the current state of medication error classification schemes reported in the literature.

3.5 Conclusions

Healthcare researchers adopt classification schemes to organise data into manageable and meaningful categories that can be analysed to inform quality improvement initiatives. There is no recommended standard for classifying medication errors or DRPs, although there are some published schemes available, which have been subjected to a process of validation. A structured and consistent approach to capturing and classifying these would provide a powerful insight into their incidence and prevalence across a healthcare setting to better inform quality and safety improvement. The uptake of such a standardised scheme may be encouraged if organisations had the opportunity to adapt elements (e.g. sub-categories) to be more specific to their environment or research question.

Chapter 4 DEVELOPING CONSENSUS ON HOSPITAL PRESCRIBING INDICATORS OF POTENTIAL HARMS AMENABLE TO CLINICAL DECISION SUPPORT

In this chapter, I describe the eDelphi technique conducted to identify high-risk prescribing indicators that are relevant to the hospital setting and amenable to CDS. I summarise the 80 indicators that were agreed by consensus and their associated harms. The indicators will be used to identify high-risk errors in the quantitative analysis of messages communicated by pharmacists to physicians via the CPOE system at UHBFT.

A summary of this chapter has been published in the British Journal of Clinical Pharmacology. I was also co-author on a similar study conducted for the paediatric setting, published in the same journal.

- Thomas, S. K., McDowell, S. E., Hodson, J., et al. (2013) Developing consensus on hospital prescribing indicators of potential harms amenable to decision support. *British Journal of Clinical Pharmacology*, 76 (5): 797-809.
- Fox, A., Pontefract, S., Brown, D., et al. (2016) Developing consensus on hospital prescribing indicators of potential harm for infants and children. *British Journal of Clinical Pharmacology*, 82 (2): 451-460.

4.1 Background and research aims

Monitoring the types and rates of errors is crucial in understanding how processes can be improved to reduce the risk of patient harm and to examine whether an intervention to improve a process has had the desired impact. Determining the potential harm of these errors and the subsequent burden to both the patient and the NHS can prove difficult. Indeed many studies choose to utilise their own severity scales for defining a level of harm. These tend to be subjectively assessed and scored by the researcher, with the potential for introducing bias, or request consensus is achieved from a number of healthcare professionals for every error found in the research (Dean & Barber, 1999; Dornan *et al.*, 2009), which can prove time consuming and costly.

Untargeted prescription chart review for potential prescribing errors can lead to a plethora of low- or no-harm errors (Avery *et al.*, 2012; Dornan *et al.*, 2009). Whilst newer processes exist for determining 'actual' harm occurrences—for example by looking at triggers that indicate harms such as the prescribing of antidote medicines or critical laboratory values (Griffin & Resar, 2009)—such processes require an intensive retrospective review of clinical records. Determining the preventable nature of such harm is also prone to subjective interpretation.

Prescribing indicators are agreed by a range of stakeholders to be a valid method to measure or monitor an area of prescribing, where there is a perceived direction in which the prescribing being measured should move over time (The Information Centre (Health Care), 2012). Previous work in general practice has identified a list of critical indicators of potential prescribing errors in the UK as a means of assessing the safety of general practitioner

prescribing (Avery *et al.*, 2011). In a similar manner, Inappropriate Prescribing (IP) criteria for older adults have been developed to facilitate chart review and identify the medications that may 'potentially' lead to adverse drug events (Gallagher *et al.*, 2008; Laroche *et al.*, 2007). However, this 'screening' tool is restricted to errors of omission and commission, is specific to a patient population and is not necessarily designed to measure prescribing over time. In Australia, hospitals are encouraged to use the 'Indicators for Quality Use of Medicines (QUM)' – a set of 30 indicators designed to measure both processes and outcomes of medication use to inform system improvement (NSW Therapeutic Advisory Group, 2007). These indicators are generally not specific to a medicine and capture data on quality rather than safety for optimal medication use rather than indicators of potential harms. Therefore, at present, there remains no validated list of prescribing indicators that have been developed for the hospital setting, or that are associated with both the highest risk of patient harm and likelihood of occurrence.

As CPOE becomes more widespread in the hospital setting, prescribing indicators should be considered that are amenable to CDS—that is the error to which each indicator refers has the potential to be prevented by such software. The use of CDS provides an opportunity to alert prescribers to potential harms (Kaushal R, 2003; Pearson *et al.*, 2009; Schedlbauer *et al.*, 2009). Such systems have been shown to substantially reduce medication error rates, but most studies have not been powered to detect differences in the rate of adverse drug events (Kaushal R, 2003). As described in Chapter 3, the methods adopted by the researchers and the study outcomes also vary, making comparisons between them difficult. Developing indicators that are amenable to CDS allows for the effects of this technology to be quantified; this is important not only given the rate at which such technologies are being

implemented but also relevant because of the heterogeneity of system configuration and complexity.

The aim of this research is to identify a list of prescribing indicators specific for the hospital setting that would aid the prospective collection of high-risk prescribing errors amenable to CDS. The results will inform the methodology for identifying high-risk errors communicated by pharmacists to the physician via a CPOE system.

4.2 Method

4.2.1 Methodological approach

The Delphi technique has been widely used in healthcare research as an approach to establish consensus in an area where published information is inadequate (Avery *et al.*, 2005; Gallagher *et al.*, 2008; Jones & Hunter, 1995). The method generally comprises a questionnaire sent to a group of experts who are asked to answer a series of questions over multiple rounds (Fitch *et al*., 2001). After each round, the responses are gathered and tabulated by the researcher and sent back to the group for the questions to be answered again. The responses from participants are anonymous during the process and the process continues until a level of agreement has been accomplished. The Delphi method is useful when there is a defined question that needs to be answered and one that does not need to be informed by direct discussion between the expert participants and the researcher, as would occur using a Nominal Group Technique (NGT) (Fitch *el al*., 2001). Unlike the NGT, the method is also less time-consuming for participants and may therefore encourage participation and a higher completion rate of the multi-stage process.

Given the specific aim of the study, the Delphi methodology was selected to gather the subjective judgements of experts regarding a defined list of prescriber indicators and to develop quantitative data from which to finalise this list. An exploratory round were planned, followed by two rounds of an electronic Delphi (eDelphi), conducted via email for participants to score indicators to identify high- or extreme-risk indicators. A consensus of at least 80% across the expert panel was planned to be achieved.

4.2.2 Expert panel selection

Participants were selected based on their clinical expertise in medication safety, as well as those with knowledge of CPOE systems who would be able to identify errors that are amenable to reduction by CDS software. Some participants were identified from a conference held by a National Institute for Health Research programme grant for applied research: *"Investigating the adoption, implementation and effectiveness of electronic prescribing systems in English Hospitals"* [RP-PG-1209-10099] as well as personal contacts. An invitation was emailed to potential participants, along with a Participant Information Leaflet to provide an overview of the eDelphi study (Appendix 2). A total of 32 experts were invited to participate in the process, of whom 20 agreed. Panellists were pharmacists, clinical pharmacologists and physicians from geographically diverse areas in England, with a range of professional grades. Consent to participate was implied, on account of each of the eDelphi rounds being completed and returned.

4.2.3 The eDelphi process

In the first instance, the inclusion and exclusion criteria for the prescribing indicators were defined (see Table 4.1). These criteria were used to construct an initial list of indicators based on clinical experience, searches of relevant UK resources and previous work conducted to define critical indicators of potential harm (Avery *et al.*, 2011; Gallagher *et al.*, 2008; Joint Formulary Committee; Medicines and Healthcare products Regulatory Agency; National Patient Safety Agency; Phansalkar *et al.*, 2012). Where possible, the original evidence base or language used by others to describe the issues was adopted to provide the context of the indicators. Each indicator was listed to state the trigger medicine(s) or class of medicine, the error process and the associated harm, for example: "*Digoxin [medicine] prescribed concomitantly [process] with a diuretic [medicine] (Risk of hypokalaemia and subsequent digoxin toxicity [harm])".* This was constructed to reduce the risk of misunderstanding and bias. The prescribing indicators were listed in a table and then circulated among a team of researchers (a clinical pharmacologist, epidemiologist and researcher in applied health research) for comments and refinement before incorporation into a questionnaire for circulation to the participants for an exploratory round.

Table 4.1 – Inclusion and exclusion criteria for the prescribing indicators

Inclusion criteria	Exclusion criteria
The indicator describes a medicine prescribed in the general adult in-patient population	The indicator describes a prescribing practice that is not routinely undertaken in the UK hospital setting
The indicator relates to a medicine prescribed at a reasonable rate in the UK hospital environment	The indicator is specific to a medicine used in a patient population other than adult inpatients (i.e. paediatric vaccination schedules)
	The indicator describes an error that would not be amenable to clinical CDS

	Extraction of data required for the indicator (from hospital care records) is unlikely to be feasible The indicator describes a failure to monitor treatment The indicator describes errors relating to the dispensing or administration of a medicine

4.2.3.1Exploratory round

The refined list of indicators was emailed to all participants enrolled in the study. They were asked to review each of the indicators and to recommend any modifications they deemed necessary. In addition, the opportunity was given for further indicators to be suggested that participants felt were missing from the initial list. The responses from this round were assessed and those that had clinical merit were included in an updated list of indicators for round one of the eDelphi. A rationale for excluding suggested indicators was provided to each of the participants to give a clearer understanding of the overall inclusion criteria. For example, one participant suggested '*Any use of naloxone or flumazenil'*– the rationale provided to the participant stated, *'This is a trigger to identify an adverse drug event, not an indicator of harm from a prescribing error'.*

4.2.3.2 Round one

Round one of the eDelphi aimed to identify the most clinically significant indicators, defined as those which would have the greatest risk in a clinical setting. Using a 5-point Likert scale, participants were asked to rank each indicator for the likelihood of it occurring in hospital and the severity of the most likely outcome should the error occur. This scale was based on that used by the former UK National Patient Safety Agency NRLS (Table 4.1) (National

Patient Safety Agency, 2008)—now part of NHS Improvement— and therefore one that UK healthcare professionals were likely to be familiar with. Acknowledging that participants' previous areas of clinical practice (e.g. oncology) may influence the scoring, they were requested to take a more general view in the interpretation of each indicator.

Table 4.2 – Scoring likelihood and severity of the errors occurring

Likelihood	**1**	**2**	**3**	**4**	**5**
Descriptor	**Rare** This will probably never occur	**Unlikely** Do not expect it to occur but it is possible it may do so	**Possible** This might occasionally occur	**Likely** This will probably occur	**Almost certain** This will undoubtedly occur, possibly frequently
Severity	**1**	**2**	**3**	**4**	**5**
Descriptor	**Insignificant** No risk of patient injury or harm and no intervention required	**Minor** Minor injury or illness requiring minor intervention	**Moderate** Moderate injury requiring intervention	**Major** Major injury leading to long-term incapacity/ disability	**Catastrophic** Leads to death, multiple permanent injuries, or irreversible health effects

When all ratings from round one had been received, the likelihood and severity scores were converted into 'risk scores' using the NRLS Risk Matrix (Table 4.2) (National Patient Safety Agency, 2008). The median scores for each indicator were then calculated across the participants in the study and the indicators divided into two groups: those where the median risk score was situated in the upper categories of 'high' or 'extreme' and those where the risk was 'low' or 'moderate'. The degree of consensus between the participants was defined as the proportion that gave a risk score in the same group as the median. The mean consensus across all of the indicators was then calculated. The target for consensus was defined as at least 80%, in order to ensure that the resulting list of indicators was

reliable. This adhered to validated consensus method for developing appropriateness scenarios (Fitch *et al.*, 2001).

Table 4.3 – Scoring likelihood and severity of the errors occurring

	Likelihood				
Consequence	**1 Rare** *This will probably never occur*	**2 Unlikely** *Do not expect it to occur but it is possible it may do*	**3 Possible** *This might occasionally occur*	**4 Likely** *This will probably occur*	**5 Almost certain** *This will undoubtedly occur, possibly frequently*
5 Catastrophic *Leads to death, multiple permanent injuries, or irreversible health effects*	**5**	**10**	**15**	**20**	**25**
4 Major *Major injury leading to long-term incapacity/ disability*	**4**	**8**	**12**	**16**	**20**
3 Moderate *Moderate injury requiring intervention*	**3**	**6**	**9**	**12**	**15**
2 Minor *Minor injury or illness requiring minor intervention*	**2**	**4**	**6**	**8**	**10**
1 Insignificant *No risk of patient injury or harm and no intervention required*	**1**	**2**	**3**	**4**	**5**

1–3 **Low risk**	**4–6** **Moderate risk**	**8–12** **High risk**	**15–25** **Extreme risk**

4.2.3.3 Round two

In round two, the full list of indicators were returned to each participant with their own individual scores for severity and likelihood shown, as well as the median scores from all members of the expert panel. This gave the opportunity for participants to modify their scores in light of the judgments of the rest of the group or to retain their original viewpoints if they did not agree with the common opinion. The median risk scores were then recalculated and the mean consensus between participants determined, as per round one. The final list of indicators comprised those where the median risk score and the scores of at least 80% of participants were in the 'high' (risk score 3) or 'extreme' (risk score 4) categories.

4.3 Results

The exploratory stage and two-round eDelphi was completed by all 20 participants. The expert panel consisted of 11 pharmacists with a sum of 122 years hospital experience and nine physicians with a sum of 60 years hospital experience (Table 4.3). All participants either worked in an academic institution or within an NHS hospital and all had an interest in medication safety and/or CPOE.

Table 4.4 – Participant demographics

Profession	Grade	Specialty	Employer
Pharmacist	Senior	Diabetes and endocrinology	NHS hospital
Physician	Registrar	Clinical pharmacology	Academic institution
Physician	F2 physician	Medicine	NHS hospital
Physician	Consultant	Clinical pharmacology	NHS hospital
Pharmacist	Teacher practitioner	Paediatrics	NHS hospital
Pharmacist	Senior	General surgery	NHS hospital
Pharmacist	Lecturer	Palliative care	NHS hospital
Pharmacist	Lecturer	Medication safety	Academic institution
Pharmacist	Senior	Oncology	NHS hospital
Pharmacist	Lecturer	Medication safety	Academic institution
Pharmacist	Lead pharmacist/lecturer	Medication safety	Academic institution
Pharmacist	Senior	Electronic prescribing	NHS hospital
Physician	F2 physician	General medicine	NHS hospital
Pharmacist	Senior	Primary Care	Interface*
Physician	F2 physician	Medicine	NHS hospital
Physician	Registrar	Respiratory medicine	NHS hospital
Physician	F1 physician	Medicine	NHS hospital
Physician	Registrar	Clinical pharmacology	NHS hospital
Physician	F2 physician	Diabetes and endocrinology	NHS hospital
Pharmacist	Lecturer	Pharmacy practice	Academic institution

F1 – Foundation Year 1 physician (junior, first year of practice post-qualification)
F2 – Foundation Year 2 physician (junior, second year of practice post-qualification)
*Works at the interface between community and hospital care

In the first instance, 210 prescribing indicators were identified; 108 of these were from published studies using similar consensus techniques (Avery *et al.*, 2011; Gallagher *et al.*, 2008; Phansalkar *et al.*, 2012), 36 from safety warnings and alerts from UK authorities (Joint Formulary Committee; Medicines and Healthcare products Regulatory Agency; National Patient Safety Agency) and 66 from clinical experience. In the exploratory round, a refined list of 89 indicators were sent to the participants and 71 additional prescribing indicators were suggested by the expert panel, of which 20 were selected for inclusion in round two

(making a total of 109). Figure 4.2 the eDelphi process and results of each stage and table 4.4 summarises the rationale for excluding 50 of the additional indicators.

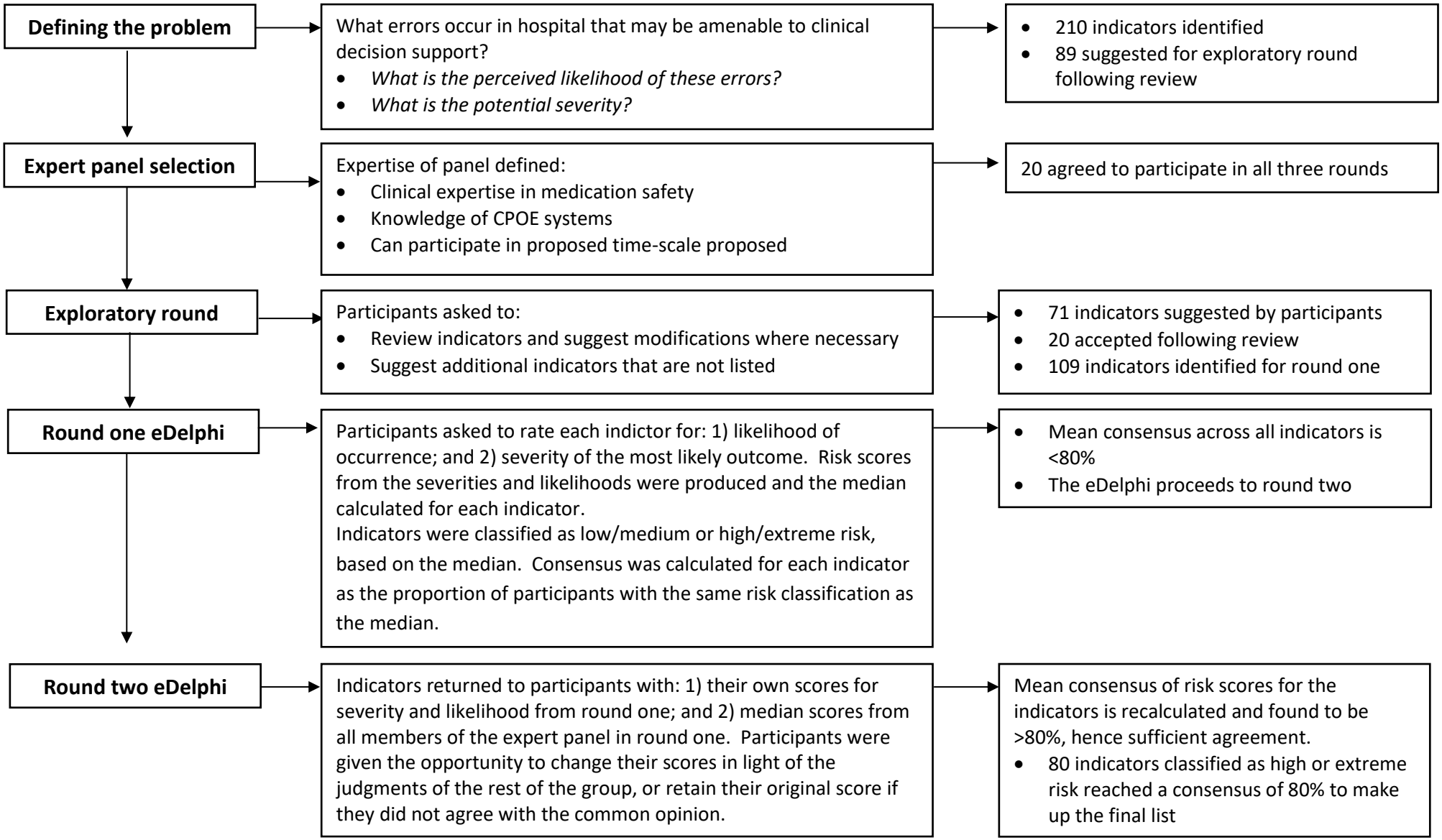


Figure 4.1 – A summary of the eDelphi process and results at each stage

Table 4.5 – Reasons for exclusion of suggested indicators in round one of the eDelphi

Reason for exclusion	No.
Modified existing indicator	2
Dependent on individual hospital guidelines	1
Difficult to assess	9
Medicine not prescribed on an in-patient basis	1
Indicator already present in list	10
Not amenable to CDS	6
Specialty specific	4
Relates to administration	8
Relates to monitoring	7
Trigger, not indicator	1
Unnecessary duplication of treatment	1
Total	***50***

A total of 80 out of 109 prescribing errors were considered high or extreme risk by consensus when the scores for likelihood and severity were considered; these were included in the final screening tool (Appendix 3). The indicators excluded in round two are summarised in Appendix 4. There were 16 indicators that achieved 100 percent consensus and 65% (n=52/80) that achieved censuses of 90% or more.

Of the 80 final indicators, the majority were synthesised from clinical experience (n=25), followed by those identified by the STOPP/START criteria (a screening tool for assessing the appropriateness of medicines or classes of medicines in older adults) (Gallagher *et al.*, 2008) (n=23), Avery *et al* (2011) (n=12), Medicines and Healthcare products Regulatory Agency MHRA and NPSA warnings (N=14) and Phansalkar *et al* (2012) (n=6). The indicators included a total of 41 different trigger medicines or classes of medicine, prescribed for: cardiovascular (n=22), central nervous system (n=28), endocrine (n=5), gastrointestinal (n=6), infection (n=12) and miscellaneous (n=7). The most common medicines and classes named in the indicators were antibiotics (n=13), antidepressants (n=8), non-steroidal anti-

inflammatory drugs (NSAIDs) (n=6), opioid analgesics (n=6), antiplatelets (n=5), methotrexate (n=4), low molecular weight heparins (LMWH) (n=4) and benzodiazepine (and like) medicines (n=4).

Participants identified five indicators as 'extreme risk', calculated using the NPSA Risk Matrix. Three of these involved anti-infective medicines (macrolides [with warfarin], gentamicin and amphotericin B), one involved a LMWH and one related to paracetamol. The most frequent error types identified as high or extreme risk were those classified as clinical contraindications (36.3%, n=29/80). This included medicines prescribed in renal impairment (n=8), heart failure (n=4) and epilepsy (n=4), as well as those that should be avoided with abnormal blood results (n=4). Drug-drug interactions were the second most common error type (28.8%, n=23/80), with antidepressants the most common interacting class of medicine (n=5).

When indicators were ranked according to median severity scores only, two out of the 80 indicators were given a score of 5: Catastrophic (see Figure 4.1): 'Amphotericin B prescribed without stating the brand name and the dose in mg/kg *(Risk of fatal overdose due to confusion between lipid based and non-lipid formulations)'* and 'Oral methotrexate prescribed to a patient with an inappropriate frequency *(Increased risk of toxicity)'.*

4.4 Discussion

This eDelphi identified 80 high and extreme risk prescribing indicators that are relevant to the hospital setting, which also have the potential to be prevented by alerts and warnings in CDS software. All 20 participants completed the exploratory round and both rounds of the

eDelphi, removing any bias potentially introduced by missing responses from people with specific expertise.

The most frequently named medicines or classes of medicines in the final list were antibiotics, opioids and LMWHs. This is consistent with those considered high-risk by the NPSA, identified in incident reports as the medicines with the highest percentage of medication incident reports with fatal and severe harm outcomes with clinical outcomes of death and severe harm (Cousins *et al.*, 2012). Indicators relating to antidepressants were also frequent, but are not listed by the NPSA as medicines with a high number of reports for fatal and severe harm. Four of these were for selective serotonin re-uptake inhibitors (SSRIs), a class of drug with a high prescribing rate in the UK, with citalopram being one of the top 20 medicines dispensed by pharmacies in England at the time of the study (The NHS Health and Social Care Information Centre, 2012).

In this study, the indicators were not restricted to one type of error. The most frequent error types associated with the indicators were clinical contraindications (36.2%, n=29/80) and drug-drug interactions (28.8%, n=23/80). In the US, a set of high-priority drug-drug interactions have previously been identified by an expert panel to help target CDS and create a list of interactions as a minimum standard for such systems (Classen *et al.*, 2011; Phansalkar *et al.*, 2012). Interestingly, only six of the 23 drug-drug interactions identified by the expert panel in this eDelphi process were the same as those previously identified by Phansalkar *et al* (2012) showing there to be a difference in opinion between what the UK and the US would consider to be highly significant. This may, in part, be due to the difference in the rate at which these medicines are prescribed in each country. However,

when the scoring for the indicators were ranked according to median severity scores only, two indicators scored '5' (catastrophic) and 26 scored '4' (major); nine of these were drug-drug interactions and only one was consistent with the list defined by Phansalkar *et al* (2012).

The prescribing indicators were developed for the hospital setting and therefore include some medicines that are not likely to be prescribed in general practice (e.g. intravenous gentamicin). However, just six such indicators out of the 80 include medicines that would only be prescribed on an inpatient basis and therefore 74 of the indicators have the potential to be applied to general practice. Indeed eight of the final indicators were taken directly from Avery *et al* (2011), which were originally developed for GP systems and were subsequently scored as high or extreme risk in this eDelphi process.

The indicators of harm identified provide an objective measure than can be implemented in the routine collection of high-risk prescribing errors in both paper-based and electronic processes. The indicators can be used for both prospective and retrospective drug chart review. The collection of standardised data allows for comparison to be made and conclusions drawn which can provide evidence for safety initiatives. With the capital cost of installing a CPOE system in a hospital being in the region of £1.5 million, research into its effect and effectiveness are crucially important. Investigating the rate of high-risk prescribing errors pre- and post- implementation in such cases is beneficial in providing evidence to support one of the primary objectives of implementing such a system—to reduce the number of medication errors and subsequent harms.

The indicators can also be used to inform the development and optimisation of CDS, with the intention of minimising untargeted or non-specific alerting which can lead to an overburdening of the prescriber and causing alert fatigue, limiting its intended effects (Riedmann *et al.*, 2011; van der Sijs *et al.*, 2008a). A Cochrane review in 2011 found that point of care computer reminders generally achieve small to modest improvements in provider behaviour (Shojania *et al.*, 2009) and concluded that further research must identify key factors—related to the design—that reliably predict larger improvements in care from such expensive technologies. The indicators developed here can help ensure that CDS target the errors that are more likely to occur and/or have the greatest potential for causing patient harm and may serve as a priority list for CDS software developers.

4.4.1 Limitations

Prior to the commencement of the eDelphi, 210 indicators were identified from both clinical experience and published literature. Of these, 130 were excluded as it was felt they were neither prescribed at a reasonable frequency nor considered to be high-risk enough for inclusion. This review process meant that many of the indicators sent to the participants could already be considered high-risk and may explain why the final list was not substantially smaller. The same 20 participants took part in both the exploratory round and the two-round eDelphi, which may further explain why consensus was reached on a large number of indicators. There may also be a risk that in the original identification step, some high-risk errors were missed, despite a robust review of the literature, or excluding some that other people would have considered important enough for inclusion. However, the exploratory round prior to the eDelphi process was designed to reduce the risk of such omissions in the final list.

All participants in the eDelphi were from geographically diverse areas in England. However, the lack of expertise from further afield may make these indicators more applicable to the UK setting. Indeed it may be of interest to see whether, for example, experts from other defined geographical regions (e.g. US and other European countries) would come to similar conclusions as UK healthcare professionals. The indicators identified are all knowledge-based errors and do not include those that may occur as a result of the use of the system. However, the methodology used in this study may be applied to capture this type of error in an organisation if the development were informed by error reports submitted over time.

Lastly, with the development of any indicator or trigger to monitor quality or safety in healthcare, its relevance should be continuously reviewed and updated. As new therapeutic agents are introduced and older ones go out of favour, the likelihood scores for their occurrence in clinical practice may well adjust and they would no longer qualify according to our methodology.

4.5 Conclusions

Prescribing errors with a high potential for causing patient harm have been identified by an expert panel. These indicators provide a standardised and validated method for the routine collection of prescribing error data in both paper-based and electronic prescribing processes. They can serve as a means to assess safety improvement, such as with the introduction of CPOE and CDS in UK hospitals. This can also be of value in the optimisation of CDS embedded within CPOE systems. The results of this study will be used to identify

whether pharmacists communicate with physicians via a CPOE system regarding high-risk prescribing errors.

Chapter 5 ELECTRONIC PHARMACIST-PHYSICIAN COMMUNICATIONS IN A HIGHLY COMPUTERISED HOSPITAL: DEVELOPMENT OF THE DATABASE

In this chapter I introduce the 'Prescribing Information and Communication System' (PICS) in use at the University Hospital Birmingham NHS Foundation Trust and the review message function to facilitate pharmacist-physician communication. I describe the method used to capture data relating to pharmacist-physician communications in PICS and provide a detailed description of how the data were coded to answer key questions. Finally, I explain how various temporal, message and prescriptions factors were coded in the database and provide an evidence-base for why this was conducted.

Sections of this methodology chapter have been published in PLoS ONE: Pontefract, S. K., Hodson, J., Marriott, J. F., et al. (2016) Pharmacist-Physician Communications in a Highly Computerised Hospital: Sign-Off and Action of Electronic Review Messages. *PLoS ONE,* 11 (8): e0160075.

5.1 Background

5.1.1 Digital health data and quality improvement

The adoption of health information technology as Electronic Patient Records (EPRs) (sometimes referred to as Electronic Health Records) worldwide and across all sectors of healthcare has generated large volumes of digital data and as more systems are implemented, the volume of data being generated is increasing and at an exponential rate (Luo *et al.*, 2016). This explosion of information is commonly referred to as 'Big data' and is often described by the four V's: Volume, Velocity, Variety and Veracity (Raghupathi & Raghupathi, 2014; Tan *et al.*, 2015). 'Variety' refers to the different forms of data; for example, data may be structured, such as with a list of pathology results or patient comorbidities, or unstructured such as with free-text documentation detailing a patient consultation or management plan. 'Veracity' refers to the accuracy of data and therefore the quality of the information.

The ability to digitise health information has revolutionised how quality improvement is approached in healthcare. The value of this data increases with the ability to link data to other sources of information. In some countries, the use of health data is mandated to drive quality—the HITECH Act in the US has developed objectives to ensure "*meaningful use of data… to achieve significant improvements in care"* (Blumenthal & Tavenner 2010).

The adoption of CPOE to facilitate the medication process has specifically enabled large quantities of data to be captured relating to the use of medicines. For the first time, questions can be asked of the prescribing and administration of medicines that would not

have been feasible (or indeed in some cases possible) in paper-based processes. For example, organisations can determine how timely medicines are being administered in hospital (Coleman *et al.*, 2013), identify and quantity adverse effects to medicines (Mohamed *et al.*, 2011) and target areas with CDS software to ensure or promote standardised care (Murdoch & Detsky, 2013).

In this study, I introduce the development of a large database, created to analyse both structured and unstructured data relating to pharmacist-physician communications.

5.1.2 Prescribing, Information and Communication System

The Prescribing, Information and Communication System (PICS) is a locally developed CPOE system in use at the University Hospital Birmingham NHS Foundation Trust (UHBFT) since 2004, although earlier parts of the system existed as early as 1998 (Nightingale *et al.*, 2000). PICS is used for the prescribing and administration of medicines throughout all inpatient beds, with the exception of the Emergency Department and some complex systemic anticancer therapies prescribed according to defined treatment protocols. It is also used to generate the discharge summary and prescription for patient discharge (known as 'to take out' prescriptions, or TTOs).

At UHBFT, pharmacists screen inpatient and TTO prescription orders that are generated in PICS for their safety and appropriateness. When the pharmacist is satisfied that an order for a medicine is appropriate, it is validated—a process undertaken to confirm an order is suitable for a patient and the action of which generates a green icon on screen to inform

other healthcare professionals it has been checked. During review, the pharmacist may wish to query a discrepancy or error, or communicate information to support the order. In PICS, a communication function exists that enables the pharmacist to communicate with the physician using an electronic 'review message'—a free-text message of up to 255 characters that can be assigned to a patient's individual prescription order (Figure 5.1–5.4).

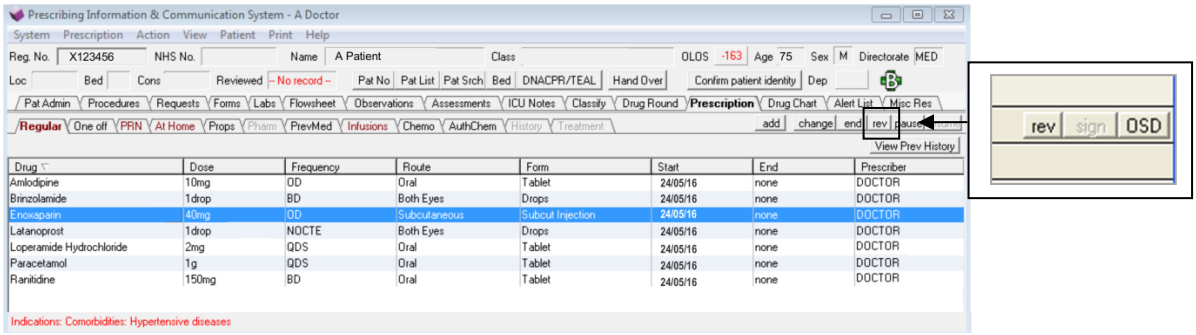


Figure 5.1 – Adding a review message to a medicine; the pharmacist highlights the medicine and selects 'Rev' [Review]

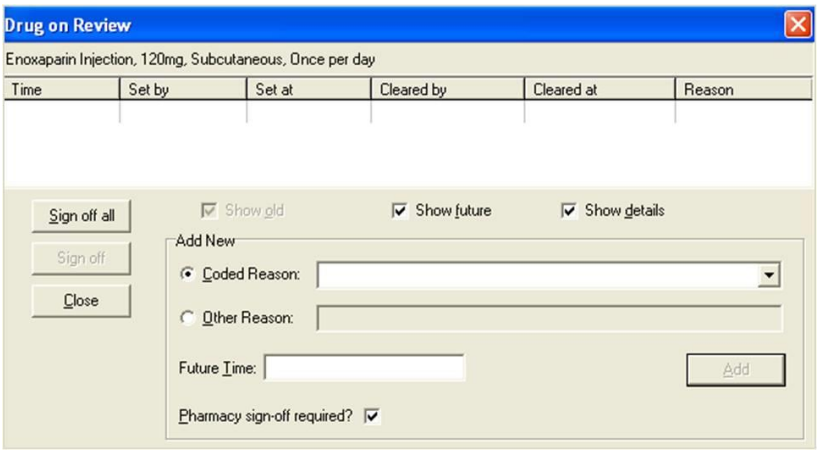


Figure 5.2 – Selecting 'Review' reveals the 'Drug on review' box

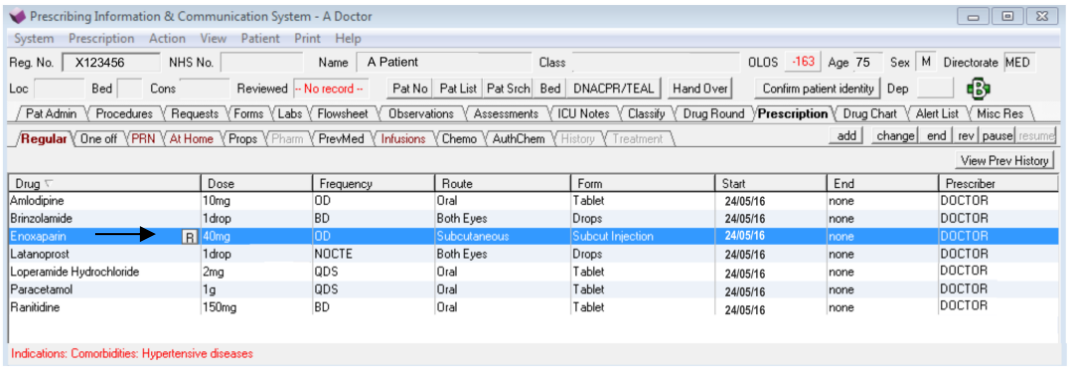


Figure 5.3 – An 'R' icon highlights the presence of a review message on a prescription

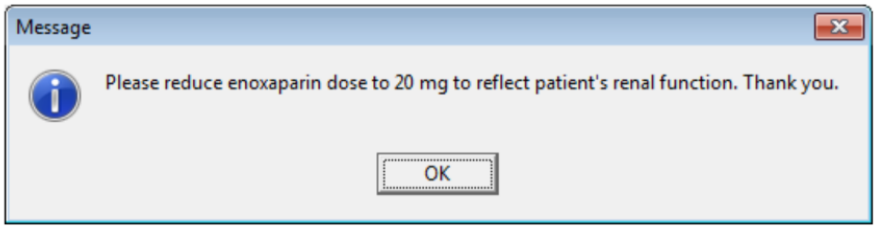


Figure 5.4 – Clicking on the 'R' icon reveals the free-text message

For the purpose of this study, key features of the review message function are as follows:

I. Delivery of the message is immediate as soon as the pharmacist commits it to the system;

II. An 'R' icon identifies the presence of a message on screen (Figure 5.3). Clicking on the 'R' icon reveals the free-text message (Figure 5.4);

III. The receipt of the message is dependent on when an intended recipient (i.e. physician) next looks at the patient's prescription profile;

IV. The message can be viewed by anyone and is not directed to a named person or team;

V. The recipient can see the name of the pharmacist who has assigned the message;

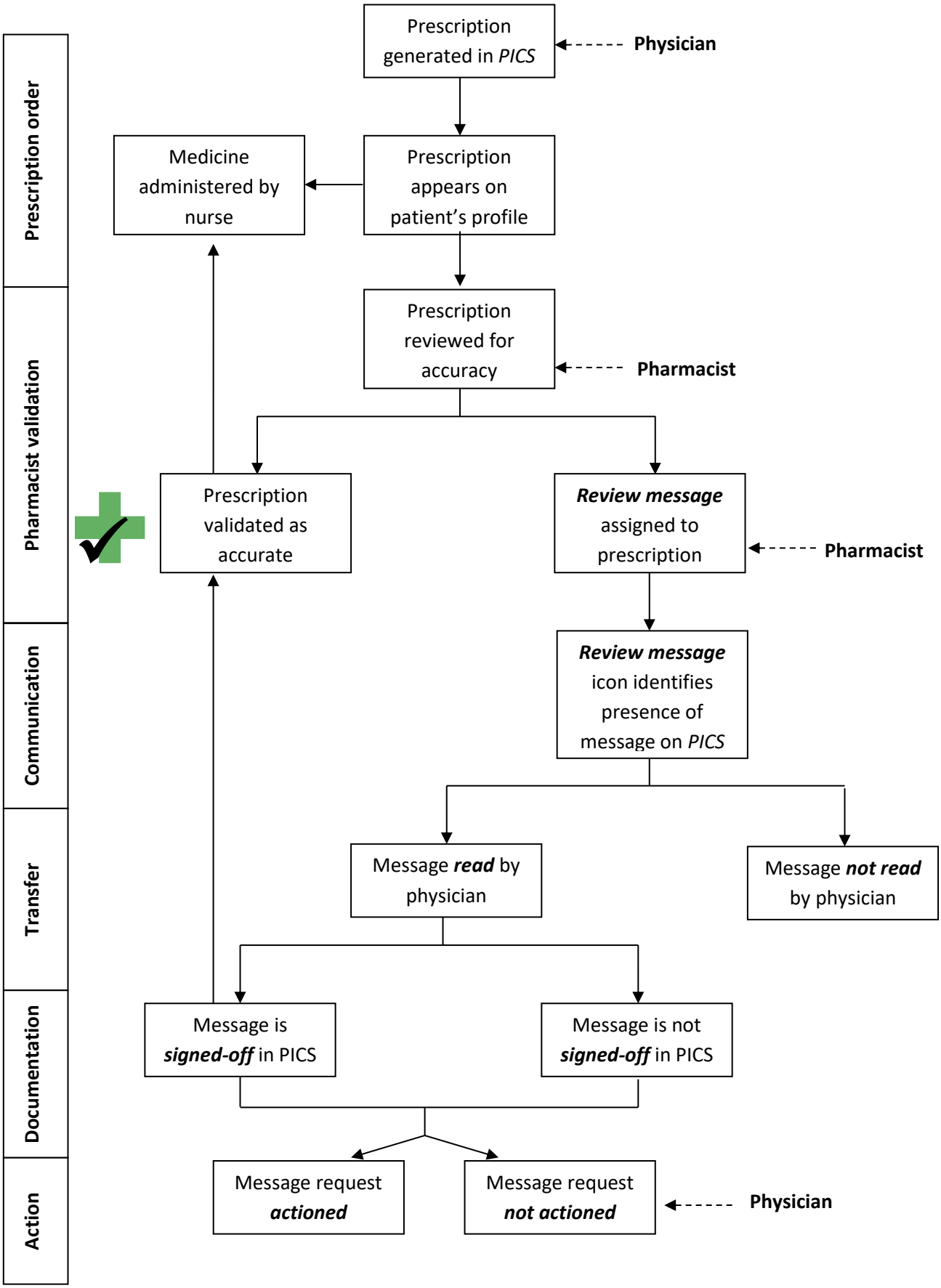
VI. For each review message, there is an option for the recipient to 'Sign-off' the message, which would be considered acknowledgement that the information has been received. Selecting 'Sign-off' removes the 'R' icon from the prescription. Messages can be signed-off by any healthcare professional. For example, if a prescription has been amended as a result of a request, but the physician failed to sign-off a message, the pharmacist may do so to remove the 'R' icon from the screen; and,

VII. The viewing and signing-off of messages is not mandated within the PICS system.

Everyone receives training on the use of PICS, adapted for the professional group. Pharmacists also receive training on the hospital's clinical pharmacy standards at the time that reflect those stated by the membership body, "*Pharmacists intervene with prescribers, patients and other healthcare professionals to ensure medicines are safe and effective*" (Royal Pharmaceutical Society, 2014).

This process of prescription validation and pharmacist-physician communication via PICS is explained in Figure 5.5.

Figure 5.5 – Schematic of pharmacist validation and communication in PICS



5.1.3 Aim and key research questions

The aim of this study was to capture pharmacist-physician communications assigned to prescription orders over a 12-month period and to code the data to enable descriptive and statistical analyses to address four key questions.

1. What type of information is communicated by pharmacists via the review message function in PICS?
2. Do physicians sign-off pharmacist review messages within PICS?
3. What factors influence the sign-off and time taken to sign-off review messages?
4. What factors influence the action and the time taken to action review messages?

5.1.4 Ethics approval

This study protocol was approved by the University Hospital Birmingham NHS Foundation Trust Research and Development Department [21st October 2013] and the University of Birmingham Ethics Committee [ERN_12-0127].

5.2 Developing the database

5.2.1 Data capture

The following data were requested from the Informatics Department at the University Hospital Birmingham NHS Foundation Trust:

I. Review messages assigned by pharmacists to medicines orders between the 1st January 2012 and 31st December 2012;

II. The details of the prescription order on which each review messages was assigned; and,

III. Details of any changes made to the order following a review message being assigned.

For each review message captured, the following information was requested:

I. Date and time the review message was assigned by the pharmacist to a prescription order in PICS;

II. Date and time the order was generated by the physician;

III. Grade of the pharmacist who assigned the review message (grade 6–8; grade 6 pharmacists generally having 0–18 months experience; grade 7 having at least 18 months experience; and 8 being the most senior). In cases where a pharmacist had recently moved grades, it was requested that the lower grade was assigned;

IV. Ward and speciality the patient was under the care of when the review message was assigned;

V. The free-text of the review message;

VI. Details of the medicine order on which the review message was assigned: name of medicine; route; dose; dose units; frequency; and the regularity of the prescription;

VII. Status of the prescription (i.e. whether it was continued (C) or deleted (D) prior to the patient receiving a dose);

VIII. Whether the review message was signed-off within the system;

IX. Profession of the user who signed-off the message (pharmacist, junior physician, registrar, consultant, or non-medical prescriber); and,

X. Date and time the message was signed-off.

The data were presented in an Excel spreadsheet, with each data entry representing a different review message on an order and with a unique identifier for each, but unrelated to the patient's personal data.

In order to ascertain any patterns in the pharmacists' use of the review message function over time, the following data were also requested between 1st January 2004 and 31st December 2014:

I. Number of inpatient prescriptions;
II. Number of prescriptions for discharge (TTOs);
III. Number of inpatient episodes; and,
IV. Number of review messages assigned by pharmacists.

5.2.2 Cleaning the data

The following review messages were excluded prior to coding for analysis:

I. Messages generated and assigned by pharmacy technicians;
II. Messages generated and assigned by pre-registration pharmacists;
III. Blank messages (no message within the free-text field);
IV. Duplicate messages that can occur when the 'add' button is clicked by the pharmacist more than once in quick succession, which commits the same message to the PICS database on more than one occasion. These were identified using the 'Conditional Formatting' function in Excel allowing duplicate cells to be highlighted; and,
V. Incomplete messages identified using a filter function in Excel.

5.2.3 Coding the data

The captured data were coded in Excel to identify a number of factors. These were informed by the data available to code and a preliminary review of the data to determine any themes that were possible to code and that would be potentially beneficial to the analysis.

i. Category of the medicine type;
ii. Presence of a high-risk medicine;
iii. The topic of the communication;
iv. Review messages communicating information relating to a pre-defined high-risk error (Thomas *et al*., 2013);
v. Review messages associated with a disparity between what the patient usually takes prior to admission and what they are currently prescribed (defined as the *medicines reconciliation* process);
vi. Review messages that were not directly associated with the medicine orders on which they were assigned; and,
vii. Messages that requested an action that could be determined from the data.

The coding strategy and rationale for each of the above factors is described in more detail below.

5.2.3.1 Category of medicine

Antimicrobial and cardiovascular medicines are commonly associated with hospital prescribing errors (Bobb *et al.*, 2004; Lewis *et al.*, 2009). In order to determine the types of medicines frequently discussed in communications, the medicines were categorised

according to those used in the UK British National Formulary (BNF) (Joint Formulary Committee). In each case, the medicine name was searched using the online BNF and a main category and sub-category was assigned. In cases where medicines or preparations of a medicine existed in more than one category (e.g. methotrexate as 'Musculoskeletal and joint diseases' and 'Malignant disease and immunosuppression'), the first category as it appeared online in the BNF was assigned, considered the most common use for that medicine. 'Anaesthetics', 'Immunological products' and 'Emergency treatment of poisoning' were all categorised as 'Other' owing to the small number of review messages assigned to medicines in these categories.

5.2.3.2 High-risk medicine

Although serious or fatal medication errors in NHS hospitals are relatively uncommon, it is accepted that certain high-risk medicines are associated with more severe harms (Cousins *et al.*, 2012). The presence of a high-risk medicine on a patient's prescription profile may affect how a prescriber prioritises or reviews treatments and was therefore identified in the dataset so that any effect on physician sign-off or action can be investigated.

The NPSA (now part of NHS Improvement) has identified common medicines or therapeutic groups of medicines that are associated with death or severe harm outcomes reported to the NRLS (Cousins *et al.*, 2012) (Table 5.1). Although a more recent systematic review of the literature has also identified ten medicines associated with hospitalisation or serious patient harm caused by medication errors (Saedder *et al.*, 2014), the number of reports analysed in this study was lower than the number of NRLS reports and the study was not specific to the UK healthcare setting.

High-risk medicines and classes of medicines listed in Table 5.1 were identified using the BNF and coded in the database using a binary code [1: positive (*medicine is associated with death or severe harms*), 0: negative (*medicine is not listed as being associated with death or severe harm).*

Table 5.1 – Common medicines or therapeutic groups of medicines associated with death or severe harm outcomes

High-risk medicines	
Adrenaline	Methotrexate
Amiodarone	Non-steroidal anti-inflammatory drugs
Antipsychotics	Opioids
Antibiotics (excluding topical)	Phenytoin
Benzodiazepines	Potassium
Insulins	Warfarin
Low molecular weight heparins	Direct oral anticoagulants*

*Direct oral anticoagulants were not included in the initial list, but have been added to account for these high-risk medicines

5.2.3.3 Topic of communication

In UK paper-based prescribing environments, pharmacists traditionally endorse or annotate the drug chart with information or instructions to support the medication process, aimed at both nurses and physicians. Research into this form of communication has shown that it is conducted to facilitate administration or "*subtly influence medical prescribing"* (Liu *et al.,* 2014). Yet, the day-to-day written discourse of pharmacists directly to physicians has not been investigated, particularly in the context of CPOE in the UK. Identifying the topic of

pharmacists' messages will not only provide insight into what pharmacists' everyday practice actually entails, but will also help determine whether the theme of a communication influences a physician's subsequent prescribing actions.

Discourse by way of an entirely free-text electronic communication means that the general theme of a communication is not pre-defined for the recipient and is therefore not available as a pre-populated structured code to facilitate analysis for research. Content analysis is a qualitative research method used to describe the key messages or elements of text data. It comprises a "*subjective interpretation of the content of text data*" (Hsieh & Shannon, 2005) and subsequent identification of themes or patterns within the data. This method is useful for quantifying unstructured data in a systematic way and thus enables statistical analyses to be performed (Green & Thorogood, 2009; pp 198-203). There are various techniques described in the literature for conducting content analysis, the selection of which is determined by the aim of the study. For example, content may be analysed inductively, a grounded or 'conventional' approach where there is no hypothesis and theory is generated or deductively, a directed approach where preliminary codes can help integrate concepts already identified (Bradley *et al.*, 2007; Hsieh & Shannon, 2005). Although the written discourse of pharmacists has not been directly investigated, the types of information or requests they might communicate to physicians is well documented and so this would support the latter of the two approaches. For example, based on the review described in Chapter 3 we know that pharmacists identify prescribing errors in the course of their clinical work and communicate with prescribers to rectify these or to instigate further discussion. We also know that errors relating to dosing of medicines and omissions are most prevalent in the UK hospital setting and are likely to make up a proportion of pharmacists'

communications (Dean *et al.*, 2002b; Lewis *et al.*, 2009; Ross *et al.*, 2013). Based on personal experience, pharmacists also provide supportive information and make proactive suggestions to optimise the use of medicines. In addition, they may also recommend alternative treatment(s) for cost-effective reasons (Bourne & Choo, 2012). In the context of CPOE, some communications may well relate to the use of the technology during the prescribing process, such as with selecting the wrong medicine from a drug dictionary or the wrong dose units (Brown *et al.*, 2017; Castro. G. M., 2016; Estellat *et al.*, 2007; Redwood *et al.*, 2011).

Content analysis of the free-text review messages were conducted to determine the various topics of communications. The review messages were filtered according to each individual medicine name and read sequentially. This ensured a systematic approach to the analysis, allowing for patterns of communication to be more easily identified for each medicine. Healthcare communications are made within a context (i.e. of a patient and their diagnosis) (Garner & Watson, 2007). Without knowledge of this context, analysis can either identify and code what is explicitly stated in text (i.e. the latent content) or what is implied (i.e. the manifest content) (Abbott & McKinney, 2013). Each of the messages were read objectively and coded with a description that summarised the explicit topic of the discourse (Abbott & McKinney, 2013; Saldana, 2013). The process was conducted iteratively, where messages were constantly compared to each other to refine the codes or to generate new ones. This method of constant comparison "*combines the explicit coding procedure (…) and the style of theory development*" (Glaser, 1967; pp 102). Analysis commences immediately with this approach and not just at the end when the coding is complete. To reduce inconsistency, a list of codes was maintained along with a description to define each. This was updated and

modified as the coding progressed and was used to prompt reflection on and refinement of the codes (Green & Thorogood, 2009; pp 202-203). As the analysis progressed, fewer topics of communication emerged from the data and codes could be more easily assigned using the framework developed. Upon completion of coding, a total of 129 different topics of communication had been identified among the review messages (Appendix 5).

5.2.3.4 Theme of communication

In order for the theme of communication to be quantified and considered a factor in any statistical analyses of the dataset, the individual codes needed to be organised into broader themes. In qualitative analysis, a theme should effectively describe the semantic relationships between the codes within it. The narrative review described in Chapter 3 was conducted to inform the coding process and to identify potential names or descriptions for themes. This identified standards for a good coding system (e.g. "*Problems defined should be clear and – if possible – leading to only one choice of coding"*) (Schaefer, 2002) and four published and validated schemes for coding medication errors and/or drug-related problems:

I. APS-Doc (Hohmann *et al.*, 2012)
II. NCC MERP (National Coordinating Council for Medication Error Reporting Prevention, 1998)
III. PCNE Classification V 6.2 (Pharmaceutical Care Network Europe Foundation, 2010)
IV. PI-Doc (Schaefer, 2002)

To identify a scheme that could be used to organise the 129 communications into themes, I conducted an exploratory Delphi to establish a level of consensus of opinion (Jones &

Hunter, 1995). A pharmacist and physician (JF, JJC) and I independently organised the 129 topics into themes described by the four different schemes. The results were compared to determine which scheme had the greatest level of consensus and which performed best at minimising the number of topics categorised as 'Other' (Table 5.2).

Table 5.2 – Number of topics of communication that achieved consensus or no consensus when categorised into the four schemes

	APS-Doc	**NCCMERP**	**PCNE V6.2**	**PI-Doc**
No. of categories in scheme	10	11	8	9
Full consensus (n/129)	67 (51.9%)	68 (52.7%)	48 (37.2%)	17 (13.2%)
Partial consensus* (n=129)	50 (38.8%)	51 (39.5%)	68 (52.7%)	82 (63.3%
Zero consensus (n/129)	12 (9.3%)	10 (7.8%)	13 (10.1%)	30 (23.3%)
Full consensus categorised as 'Other' (n/129)	28 (21.7%)	42 (32.6%)	13 (10.1%)	0 (0.0%)

*Partial consensus, 2/3 participants agreed.

Out of the four schemes, APS-Doc (Hohmann *et al.*, 2012) was found to achieve both a high level consensus (51.9%, n=67/129) and performed well at minimising the number of codes categorised as 'Other'. As such, this scheme was identified to facilitate and inform the development of a bespoke scheme to categorise topics of pharmacist-physician communication in PICS.

The APS-Doc scheme was modified to categorise the topics of communication into one of ten themes. Each theme was then described, along with an example of the type of codes it would encompass (Table 5.3). The 129 topics identified in section *5.2.3.3* were listed in a column in an Excel spreadsheet, along with the modified APS-Doc themes pre-populated in

a drop down list to facilitate coding. Using a consensus technique, the same three participants (SP, JF, JJC) independently categorised each topic into a theme. The results were combined and consensus determined. Codes that did not achieve consensus were highlighted and participants were given the opportunity to reconsider their selection based on other participant's (anonymised) selections. Any disagreements after the second round were discussed in order to reach consensus.

The first round of the eDelphi achieved a consensus of 69.0% (n=89/129) and a further 28.7% (n=37/129) were agreed by two out of three participants (Table 5.2). Only 2.3% of the codes (n=3/129) had zero consensus. After the second round, consensus of 98.4% (n=127/129) was achieved and the remaining two codes were agreed by two out of three participants (SP, JJC). These two codes were discussed and consensus on all themes was achieved. This process of consensus resulted in the 129 codes categorised into ten themes of communication (Appendix 5), a summary of which is provided in Table 5.3. The eDelphi process is summarised in Figure 5.6.

Table 5.3 – Modified APS-Doc: description of the themes and examples of the topics (codes) within each theme

Main category	Brief description	Examples of medication-related topics of communications	Example of pharmacist review message
Contraindication	*Communication relates to a contraindication to treatment that requires attention or monitoring*	Physiological contraindication exists	[Bisoprolol] *Patient is currently hypotensive, please do not administer if patient is hypotensive.*
		Contraindication exists owing to other disease state	[Nitrofurantoin] *eGFR is less than 60 = please change to trimethoprim.*
		Contraindication exists owing to allergy or intolerance	[Trimethoprim] *Patient allergic to co-trimoxazole - contains trimethoprim.*
		Potential contraindication as a result of cross-reactivity due to allergy status	[Meropenem] *Patient is allergic to penicillin, if beta lactam allergy, please review and consider alternative.*
Dose/ frequency	*Communication relates to the dose or frequency of a medicine*	The dose is too high or low for the patient or indication	[Enoxaparin] *Please consider dose reduction to 20 mg daily, patient's eGFR= 23.*
		The wrong dose has been prescribed on conversion of the drug route/form	[Citalopram] *Pls review 20 mg tablet = 16 mg (8 drops)-supplied for NG [nasogastric] administration.*
		The wrong dose units have been prescribed	[Vancomycin, 1 milligram] *Please amend dose to 1 gram BD.*
		The total daily dose has been divided inappropriately for the indication or patient	[Senna] *Pt usually takes ONE BD* [twice a day], *please review.*
		The frequency is too high or low for the patient or indication	[Meropenem] *Please review dose of Meropenem, should be BD* [twice a day] *in view of eGFR.*
		The regularity of the prescription needs reviewing (e.g. when required to regular)	[Lactulose, when required] *Most effective when used regularly, please review.*

Main category	Brief description	Examples of medication-related communications	Example of pharmacist review message
Drug form/route	*Communication relates to the form, preparation or route of administration of a medicine*	Inappropriate form of medicine for patient or indication	[Lansoprazole capsules] *This patient was prescribed Fastabs prior to admission.*
		Inappropriate pharmacokinetic form for patient or indication (e.g. modified-released)	[Propiverine] *This dose is intended to be the XL preparation - please review.*
		Inappropriate route for indication or medicine	[Chloramphenicol ear drops] *Patient was using chloramphenicol ointment for the right EYE, please review.*
		Inappropriate use of multiple routes of administration	[Ranitidine] *Please prescribe IV or oral. Frequency not equivalent (IV must be TDS* [three times a day]*).*
		Alternative route recommended for optimal treatment	[Filgrastim] *Please review route due to low platelets should be given IV infusion.*
Drug interaction	*Communication relates to a drug interaction that may require attention or monitoring*	Pharmacokinetic drug interaction	[Simvastatin] *Please pause whilst on clarithromycin, increased risk of myopathy.*
		Pharmacodynamic drug interaction	[Tramadol] *Increased risk of CNS toxicity when tramadol given with SSRIs. Please monitor.*

Main category	Brief description	Examples of medication-related communications	Example of pharmacist review message
Drug selection	*Communication relates to the selection of the prescribed medicine*	Unsuitable for indication	[Rifampicin] *Micro results show rifampicin resistance - please review appropriateness of this drug.*
		Wrong strength of medicine/preparation has been prescribed	[Seretide® 250] *Patient uses Seretide 125 evohaler 2 puffs BD - please amend.*
		No indication	[Metronidazole] *C diff negative. Is this still needed?*
		Use of two medicines with the same active substance	[Paracetamol] *Regular co-codamol prescribed please review prn* [when required] *paracetamol*
		Use of two medicines in the same therapeutic group	[Lactulose] *Please review use of Laxido and lactulose - therapeutic duplication - both osmotic laxatives*
		Sub-optimal drug choice according to guidelines	[Cefotaxime] *First-line treatment for meningitis is ceftriaxone 2 g BD.*
		Wrong brand (preparation) selected for patient or indication	[Ferrous sulphate] *Pt takes ferrous fumarate 210 mg BD - Please review*
		Wrong medicine prescribed as a result of a selection error in an electronic prescribing system	[Clonazepam] *Patient does not take clonazepam - see medical notes - patient is prescribed clobazam 20 mg on alternate evenings*
Drug use/ administration process	*Communication relates to the use of the medicine or the administration process*	Timing of administration is inappropriate for the patient, medicine or indication	[Dexamethasone] *Please amend timing of doses so that last dose each day is no later than 5pm.*

Main Category	Brief description	Examples of medication-related communications	Example of pharmacist review message
		Medicine has not or is not being administered as intended	Fluoxetine] *Please review - patient refusing doses.*
		Patient unable to take/use or be administered the medicine	[Citalopram] *Dr please review to change to drops as pt [patient] having difficulty swallowing.*
		Inappropriate medicine device for patient or indication	[Seretide Accuhaler®] *Please review to evohaler as per dhx* [drug history].
		Dose is immeasurable for administration	[Enoxaparin] *Treatment dose enoxaparin = 1.5mg/kg 1.5*83 = 124.5 mg - round to 120 mg. Please review dose.*
		Duration of prescription is unsuitable or no longer suitable	[Phosphate effervescent] *Please end as PRN phosphate only prescribed on critical care wards.*

Main category	Brief description	Examples of medication-related communications	Example of pharmacist review message
Logistics	*Communication relates to the logistics of the medication process*	The medicine is not available for supply or administration	[Calcichew D3 Forte®] *Calcichew D3 forte is non-formulary, please switch to Adcal D3.*
		The prescription is incomplete	[Fentanyl, TTO] *Needs CD* [controlled drug] *form.*
		The prescriber does not have authority to prescribe the medicine	[Capecitabine] *Only registrar or consultant to prescribe chemotherapy.*
		The prescription is for the wrong patient	[Fentanyl] *To be removed - written for wrong patient.*

Main category	Brief description	Examples of medication-related communications	Example of pharmacist review message
Omission	*Communication relates to an unintentional omission of treatment*	Omission of a medicine taken by a patient prior to admission	[Salbutamol] *Pt also uses Symbicort 400/12. Please review.*
		Omission of a required medicine on the discharge prescription	[Metronidazole] *Please add to TTO.*
		Omission of a treatment to optimise management	[Adcal D3] *Please note low Hb* [haemoglobin] - *please could iron supplements be considered.*
		Omission of a prophylactic treatment	[TEDS stocking] *Enoxaparin also recommended from thrombosis risk assessment.*
Supporting information	*Communication of supporting information or request for supporting information*	Monitoring requirements for treatment	[Amiodarone] *Monitor TFTs* [thyroid function tests].
		Provision of information about the patient that may aid decision-making	[Lansoprazole] *Patient stopped taking this as it was ineffective. He was taking correctly, compliantly and with no drug interactions that would prevent effect*.
		Provision of information about the medicine that may aid stages of the medication process	[Levetiracetam] *Consider increasing after 1-2 weeks to 250 mg twice daily as per BNF dosing.*
		Other supporting information	[Enoxaparin] *Low platelets please review.*
Other	*Communication relating to other medication-related issue that is not covered by the other categorises and descriptors*		[.aprepitant] *Aprepitant is in the PICS dictionary; please do not create a new drug.*

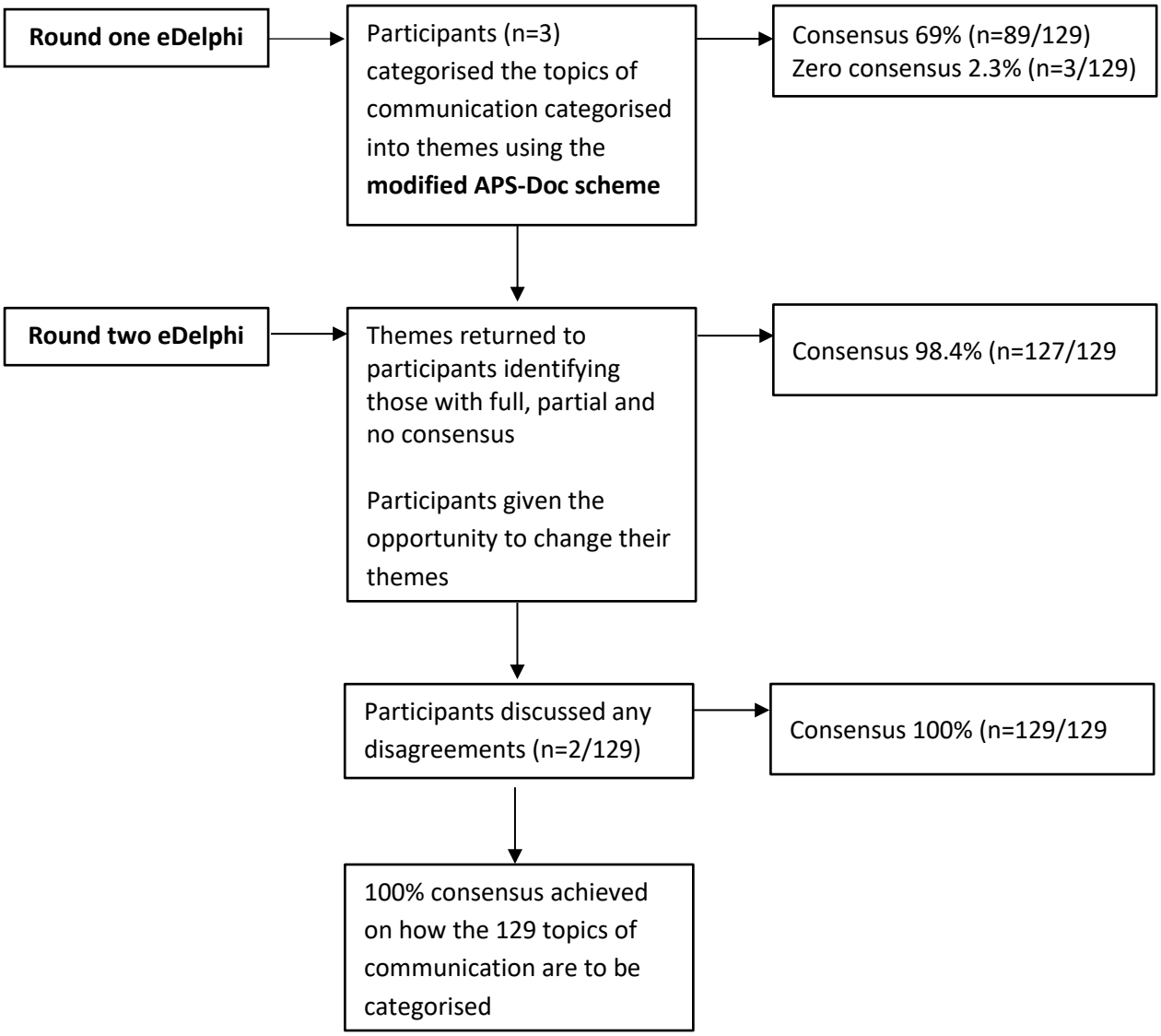


Figure 5.6 – Flow chart to show rounds one and two of the eDelphi to achieve consensus

5.2.3.5 High-risk error

Assigning a severity to a patient safety incident or near miss event is an important step in the risk assessment process and common practice in the UK healthcare setting. However, it requires agreement by consensus to determine a reliable mean score of severity—a time consuming process requiring up to four independent judges (Dean & Barber, 1999). Coding the review messages to identify those that may relate to error and subsequently assigning a potential severity would require assumptions to be made of the data without context of the

patient or the situation. However, it would be beneficial to find out if pharmacists communicate information relating to high-risk errors via the CPOE system and if so, whether this factor influences subsequent outcomes. In Chapter 4, I described a two-stage consensus technique to identify 80 high-risk prescribing errors (indicators) in the hospital setting [Appendix 3] (Thomas *et al.*, 2013). During the review of messages, communications relating to one of the 80 indicators were highlighted using a binary code [1: positive *(error is one of the high-risk indicators)*, 0: negative *(error is not one of the high-risk indicators).* These were further categorised according to which one of the 80 indicators of error the communication related to.

5.2.3.6 Messages relating to medicines reconciliation

Errors of unintentional omission are repeatedly identified as the main type of medication error in UK hospitals, with the prevalence highest on admission (Cousins *et al.*, 2012; Donyai *et al.*, 2007; Dornan *et al.*, 2009; Ross *et al.*, 2013). It was therefore expected that a proportion of messages communicated in PICS would relate to this discrepancy. Medicines reconciliation "*is the process of identifying an accurate list of a person's current medicines and comparing them with the current list in use, recognising any discrepancies and documenting any changes"* (National Institute for Health and Care Excellence, 2015). Messages relating to this process on admission to hospital were identified using a binary code [1: *positive (error relates to reconciliation on admission*), 0: negative (*information does not relate to reconciliation on admission*]. Communications that discussed discrepancies at discharge were not coded as being related to medicines reconciliation, since the formal process of reconciliation at the hospital is performed and documented on patient admission.

5.2.3.7 Speciality

Findings from studies suggest that some clinical specialities may have higher prescribing error rates than others, for example, those that write fewer prescriptions such as surgical specialties (Dean *et al.*, 2002b; Singh *et al.*, 2009). The speciality the patient was under when the message was communicated was identified. The hospital specialities were categorised as shown in Table 5.4.

Table 5.4 – Speciality the patient was under the care of when the review message was assigned

Speciality	Directorate within category
General Medicine	
General Surgery	
Medical Admissions	
Trauma and Orthopaedics	
Critical Care and Burns	Critical Care; Burns
Medical Specialities	Renal; Liver; Neurology; Cardiology; Haematology; Oncology; Ambulatory Care
Surgical Specialities	Ear, nose and throat; Cardiothoracic; Maxillofacial; Plastics; Urology; Vascular

5.2.3.8 Association of message and prescription

A review message in PICS can only be assigned to an active prescription order on a patient's profile. Should a pharmacist wish to communicate information via the CPOE system unrelated to any of the listed orders for a patient, they are forced to assign the message to one that it is not directly discussing it. A good example of this would be a communication relating to an omission of treatment. Identifying the number of messages that are

unrelated to the prescription order may inform system design relating to this. As such, messages unrelated to the assigned medicine were identified using a binary code [1: positive (*message relates to the medicine order on which it is assigned*), 0: negative (*message is not related to the medicine order on which it is assigned*).

5.2.3.9 Messages requesting an action

The messages were reviewed to determine if they requested a measurable action that could be determined from the database. For example, a message requesting a dose change to a specified alternative dose could be coded, whereas a message that provided supportive information (e.g. to monitor biochemistry) could not. Messages requesting an action were identified using a binary code [1: positive (*message requests a change in the prescription that is measurable from the database*) 0: negative (*message does not request a change in the prescription that is measurable from the database*).

When the coding of factors was complete, the database could be interrogated for analysis and additional data requested where necessary.

5.3 Determining action

5.3.1 Data capture

The following data were identified from the database described and coded in section 5.2:

i. Messages associated with the prescription on which it was assigned (see 5.2.3.8); and,
ii. Messages that requested an action that could be determined from the data (5.2.3.9).

The data were separated into a separate Excel spreadsheet, along with the unique identifier for each line of coded data. Data were requested from Informatics for each unique identifier on:

i. Prescriptions that had a documented change in PICS after a review message had been assigned;
ii. Details of the changed prescription: medicine name; route; dose; dose units; frequency; and the regularity of the prescription; and,
iii. Date and time changes were executed in PICS.

5.3.2 Coding the data

The data were coded to identify whether the prescription was changed according to the pharmacists' request in the review message. Data were filtered by the subject of the communication (i.e. code) and the components of the new prescription order analysed. Data were coded as outlined in Table 5.5—a process that occasionally required application of clinical knowledge relating to the prescription order in question.

Table 5.5 – Coding of next action data

Action	Code	Binary code
No further changes made to the prescription	No action	0
Changes to prescription, but request not actioned	No action	0
Request actioned	Correctly actioned	1

5.4 Inter-rater reliability

In the development of the review message database, a proportion of the coding required qualitative content analysis. Inter-rater reliability can provide a numerical score of agreement or consensus and is common practice in quantitative studies as a measure of consistency and therefore reliability. However, its value in qualitative research is debated owing to the inherent subjectivity of the analysis (Armstrong *et al.*, 1997) and the varying methods adopted (Cook, 2012). Despite its limitations, it was important to determine whether the messages in the database were reviewed and coded explicitly as intended and not implicitly, potentially influenced by prior experience and biases of a single reviewer.

5.4.1 Method

An independent statistician selected 5% (n=1,722) of the review messages at random using the 'RAND()' (random) function in Microsoft Excel to generate a decimal (between 0 and 1) for each of the lines. Those that were less than 0.05 (i.e. approximately 5% of the sample) were identified to be part of the validation set and prepared for independent review. The dataset contained:

i. Details of the prescription on which the review messages were assigned: name of medicine; route; dose; dose units; frequency; and regularity of the prescription; and,
ii. The free-text review message.

The rater was asked to code messages for three factors: 1) their relation to the medicines reconciliation process; 2) whether they were associated with the prescription on which they were assigned; and, 3) the theme of communication. To facilitate coding of the theme of

communication, the rater was provided with the definitions of each theme (Table 5.3). Inter-rater agreement was calculated according to the percentage of times the raters agreed. Any disagreements were identified and discussed to see whether they could be resolved by consensus. After discussion, the final percentage agreement was determined. Any outstanding disagreements were assessed in further detail to check for any inconsistencies that may have indicated a problem with the coding process.

5.4.2 Results

A total of 1,722 review messages were independently coded for three factors: 1) their relation to the medicines reconciliation process; 2) whether they were associated with the prescription on which they were assigned; and, 3) the theme of communication. The level of consensus between the two raters is shown in Table 5.6, describing agreement following the three steps in the process: 1) independent coding; 2) review of disagreements non-blinded to the original code; and, 3) discussion of the disagreements.

Table 5.6 – Rater agreement across the three factors

Step	Factor	Agreement % (n/1722)	Disagreement % (n/1722)
	Message associated with the prescription		
1	Independent coding	98.0% (n=1687)	2.0% (n=35)
2	Review of disagreements, non-blinded	98.5% (n=1697)	1.5% (n=25)
3	Discussion	99.4% (n=1711)	0.6% (n=11)
	Message relates to medicines reconciliation		
1	Independent coding	94.8% (n=1633)	(5.2% (n=89)
2	Review of disagreements, non-blinded	96.6% (n=1663)	3.4% (n=59)
3	Discussion	97.5% (n=1679)	2.5% (n=43)
	Theme of communication		
1	Independent coding with a summary of the themes (Table 5.4)	86.9% (n=1497)	13.1% (n=225)
2	Independent coding with how all codes were categorised into themes (Appendix 5)	98.3% (n=1693)	1.7% (n=29)
3	Discussion	98.8% (n=1702)	1.2% (n=20)

The assessment of inter-rater reliability showed substantial agreement across the three factors, all of which improved when additional resources were provided and with later discussion. In cases where there were disagreements, these were then assessed in further detail to identify any commonality that would indicate a systematic error in the coding. This highlighted some instances where codes required more detailed descriptors and, therefore, refinement of the description of the code in the methodology. Examples of disagreements prior to discussion and subsequent agreement and final disagreements are provided in Tables 5.7 and 5.8.

Table 5.7 – Examples of inter-rater disagreements prior to discussion and consensus was achieved

Review message	Code	Second rater	Comment on agreement
Message associated with the prescription			
Pls [please] *change discharge letter - changes have been made to regular meds*	Yes	No	This was coded as associated with the prescription, with changes made that now need to be reflected on the TTO.
Pt [patient] *on inhaler at home - Salbutamol evohaler - 2 puffs BD prn* [twice a day when required]	Yes	No	This message was assigned to a salbutamol prescription of a different preparation (nebules) indicating what should be prescribed as the patients 'usual' regimen.
Message relates to medicines reconciliation			
Was on mst [morphine sulfate tablet brand] *sachets?*	No	Yes	This message was assigned to a TTO prescription for codeine phosphate. The message was coded as unrelated to the medicines reconciliation process on admission.
Patient not had any for weeks, not appropriate to give on TTO, please review	No	Yes	This message was assigned to a TTO prescription and does not describe reconciliation on admission.
Theme of communication			
Adcal D3 pre-admission ONE BD [twice a day]	Omission	Drug selection	The theme was coded as 'Omission' and the fine code as 'Takes as combination preparation but only single constituent prescribed'. The second rater agreed with the fine code.
Patient has a falls risk - please consider using a less sedative antihistamine	Contraindication	Supporting information	The theme was coded as 'Contraindication' and the fine code as 'Drug-disease interaction – falls'. The second rater agreed with the fine code.

Table 5.8 – Examples of messages with no inter-rater agreement

Review message	First coded	Second rater	Comment on disagreement
Message associated with the prescription			
Please update thrombosis assessment	Yes	No	This in an example of experience informing coding. This message was coded as associated with the prescription since the medicine is being used for cancer, which would increase the risk of thrombosis.
Please r/v whether required with Aspirin	No	Yes	This message was likely associated with the aspirin prescription. This can be considered an error in coding.
Message relates to medicines reconciliation			
Is this new? [Atenolol] *Not in pts* [patient's] *own meds and dose listed in notes is 50 mg daily*	No	Yes	This message does relate to reconciliation and can be considered an error in coding.
Pt [patient] *does not have nebuliser at home - please change to inhaler*	No	Yes	The rater felt that this does relate to reconciliation. The first coder argued that it concerns the discharge process.
Theme of the communication			
Please review dates-needs to start 4 mg daily from [date]	Supporting Information	Drug Use/ Administration	The theme was coded as 'Supporting Information' and the fine code as 'Information provision - Duration of treatment'. The rater disagreed that this related to the duration of treatment.
Normally uses tamsulosin M/R 400 micrograms capsules once daily	Drug Use/ Administration	Drug selection	The theme was coded as 'Drug Form/ Route' and the fine code as 'Change to MR formulation to be consistent with pre-admission medicines'. This was a coding error since the message was assigned to a different medicine.

After independent coding (step 1), the rate of consensus was lowest for the theme of communication, with a disagreement rate of 13.1%. At this stage the rater had access to a list of the themes, a description of each and examples of subjects within the theme (Table 5.4). When this resource was expanded to include the full list of codes within each theme (Appendix 5) (step 2), disagreement fell to 1.7%. This degree of change shows an agreement for the codes of communication to describe the contents of the review messages, but suggests that the second reviewer may have "*packaged the themes differently*" into major themes (Armstrong *et al.*, 1997). This finding is consistent with the difficulties already faced when attempting to gain consensus on the categorisation of communication themes described in Chapter 3 and in section 5.2.3.3.

The initial coding of the dataset took just over 18 months, a long time for a single reviewer to be immersed in the data and to become familiar with the nuances of the free-text communications. During this time, the codes were refined as messages were continuously compared to each other across the entire dataset. A second rater is unlikely to view the messages in exactly the same way, since they did not have the opportunity to compare and refine codes over the same period of time. It is also important to note that the approach of constant comparison "*is not designed to guarantee that two analysts working independently with the same data will achieve the same results*" (Glaser, 1967). Despite this, the level of agreement was high.

5.5 Strengths and limitations of the database

The database of pharmacist-physician communications comprises over 34,000 free-text review messages, with additional information on the associated prescriptions and user interaction. The volume and veracity of the database is a clear strength, the latter of which has been demonstrated with a high inter-rater reliability, despite the subjective interpretation of data necessary for content analysis. In addition, the individual factors coded within the database give it variety to inform a more comprehensive descriptive and statistical analysis of electronic communications.

The coding of the database was supported with both a clear rationale for each factor and evidence-base where possible. In coding the theme of communication, where evidence did not exist to inform the process, additional research was conducted to gain consensus and improve the validity of the study.

In the development of this database, free-text communications were reviewed and coded to identify the explicit subject of the discourse and not what may be implied. The latter is not possible without knowing the individual pharmacists and running an analysis of their intent and the subsequent interpretation of the recipient. In addition, a lack of context at the time of the message (i.e. of the patient and situation) makes this difficult. Communications were also analysed and validated by pharmacists and not physicians who were the intended recipients of messages.

The language used by pharmacists in their written discourse was not analysed in this study. For example, whether pharmacists wrote with due consideration of the recipient (the

physician) or how the discourse changes to position the recipient's response (Gee, 2014). A pharmacist's discourse may change depending on their grade or prior experience, for example the use of '*?*' before a written request has been suggested to counterbalance that an action is being requested (Liu *et al.*, 2014). This type of analysis could provide further explanation for the outcome of communications, but was outside the scope of this study.

Finally, the communications were not analysed for their potential impact on patient safety. This is difficult to determine without context of the patient or the situation and would have required assumptions to be made of the data.

Chapter 6 DESCRIPTIVE ANALYSIS OF PHARMACIST-PHYSICIAN COMMUNICATIONS

In this chapter, I provide a descriptive account of the review message database captured over a 12-month period. I describe the various temporal, message and prescription factors associated with the messages assigned to prescriptions in PICS by pharmacists and present the results using tables and graphs.

Some of the results presented in the chapter have been published in a report published by NHS England: Office of the Chief Pharmaceutical Officer, M. D. (2016). Transformation of seven day clinical pharmacy services in acute hospitals. Case Study: Pharmacist-physician communication across the working week. NHS England, London (pp. 14).

6.1 Data analysis

In Chapter 5, various factors were introduced that were coded during the analysis of the database. Each of these can be divided into temporal, message and prescription factors (Table 6.1).

Table 6.1 – Factors coded for in the analysis of pharmacist review messages

Temporal factor
Day of the week messages are assigned
Hour of day messages are assigned
Time between prescription being generated and message being assigned
Message factor
Grade of the pharmacist
Message assigned to a high-risk medicine
Message associated with the prescription
Message relates to the reconciliation process
Theme of communication
Message relates to a high-risk error
Prescription factors
Speciality the patient is under the care of in the hospital
Type of medicine
Regularity of medicine

The data captured and the various factors coded in Microsoft Excel (Table 6.1) were summarised using descriptive statistics and represented graphically to highlight patterns or trends. The changes in the numbers of patients, prescriptions and review messages assigned to each in PICS between 2009 and 2014 were analysed using linear regression models. Totals and rates were calculated for each of the months and set as dependent variables in the regression models, with the month number as the independent variable. The coefficients of the resulting models were used to estimate the average annual increase in each of these outcomes.

The length of the messages as the number of characters was calculated using the LEN function in Microsoft Excel. A non-parametric approach was used as the distribution of the data was skewed (Figure 6.1). Data were reported as medians and interquartile ranges and comparisons between the grades of the pharmacists and the theme of communication were performed using the Kruskal-Wallis test. Where significant differences were detected, post-hoc pairwise comparisons between the categories were conducted using Dunn's test. All analyses were performed using SPSS 22 (IBM SPSS Inc., Chicago, IL, USA), with $p<0.05$ considered significant.

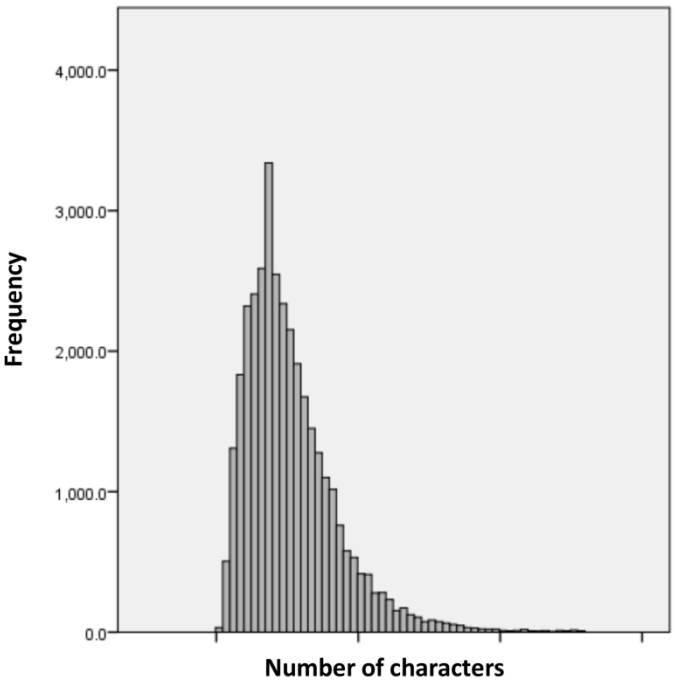


Figure 6.1 – Distribution of data by character length of review messages

6.2 Use of the review message function

Over the five-year period between January 2009 and December 2014, the number of patient admissions recorded in PICS increased from 52,977 to 89,899 per year. The number of prescriptions generated for patients increased from 1,059,252 in 2009 to 1,625,307 in 2014—a rise of 53.4%. Upon conducting a linear regression analysis, the rate of increase was found to be significant, increasing by 652 each year ($p<0.001$). Similarly, there was a significant increase in the number of prescriptions generated, increasing by 9,735 each year ($p<0.001$).

Linear regression analysis found a significant increase in the rate of messages assigned to patients, with a 2.9 percentage point increase per annum (95% CI: 2.12–3.65, $p<0.001$), as well as a 0.2 percentage point increase per annum for messages assigned to prescriptions (95% CI: 0.18–0.25, $p<0.001$) (Figure 6.2). Looking at the study period of 2012 (Figure 6.3), January and August had the highest rate of messages assigned to prescriptions, with 3.2% of all prescriptions having a review message assigned, compared to April with 2.4% of prescriptions.

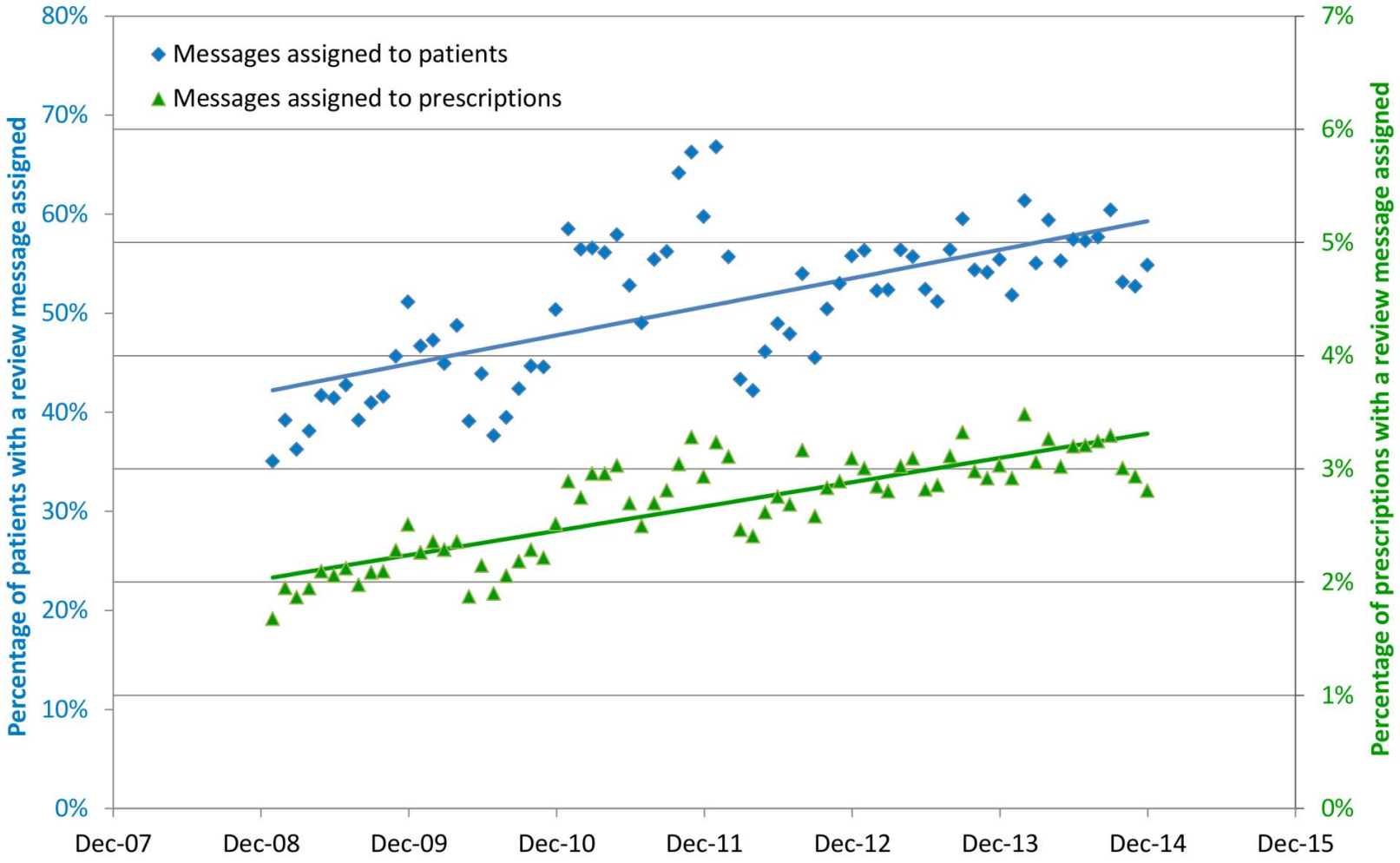


Figure 6.2 – Percentage of patients and prescriptions with a review message assigned between 2009 and 2014

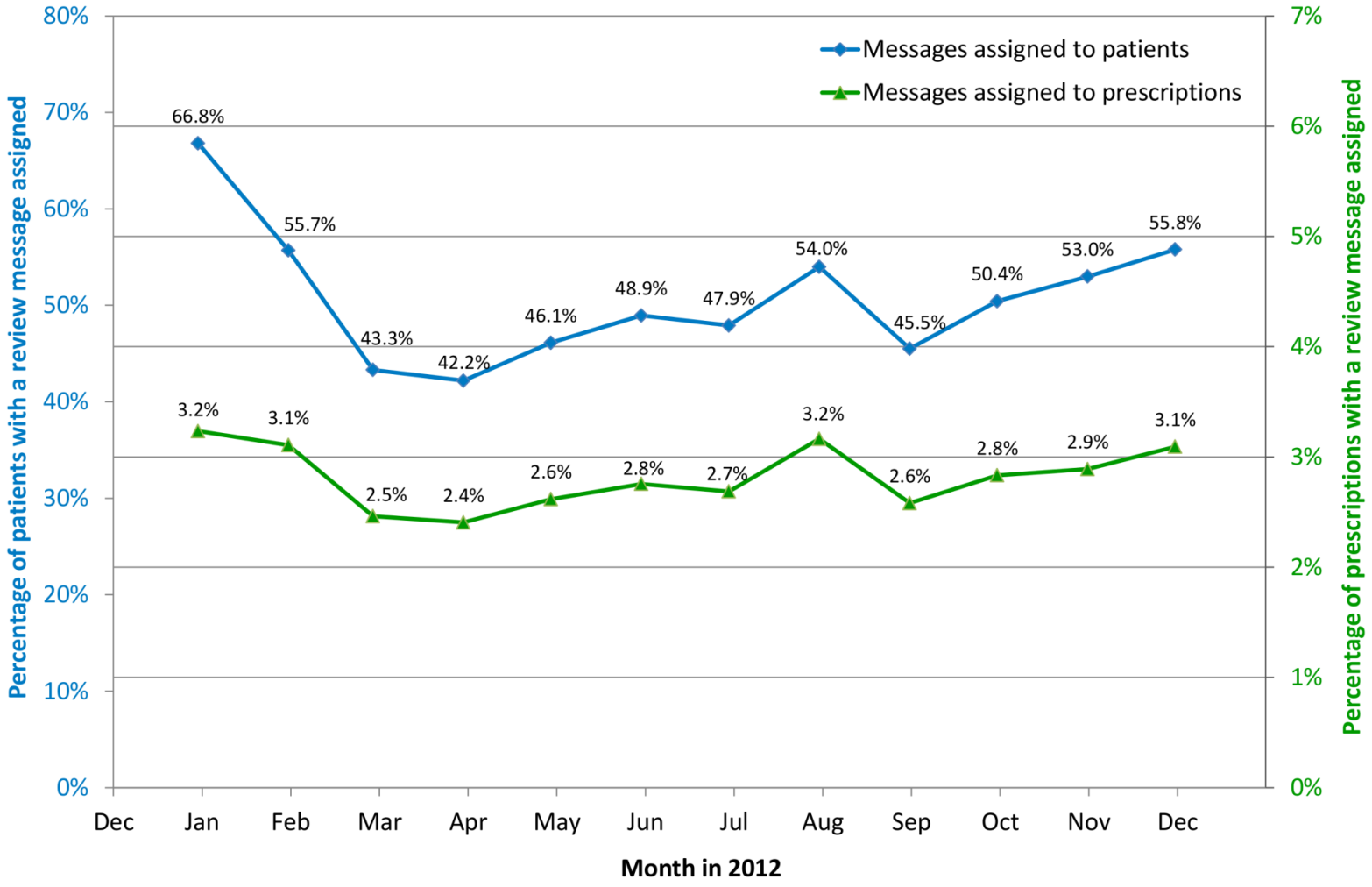


Figure 6.3 – Percentage of patients and prescriptions with a review message assigned in 2012

6.3 The Database

Between 1st January 2012 and 31st December 2012 there were 71,994 inpatient episodes generated in PICS, for whom 1,291,773 prescriptions were generated. Of these, 925,035 were inpatient orders and 366,738 prescriptions for discharge (TTOs). Pharmacist's assigned 36,245 review messages to prescriptions. After exclusions, the final database comprised 34,506 messages and associated prescriptions for analysis (Figure 6.4).

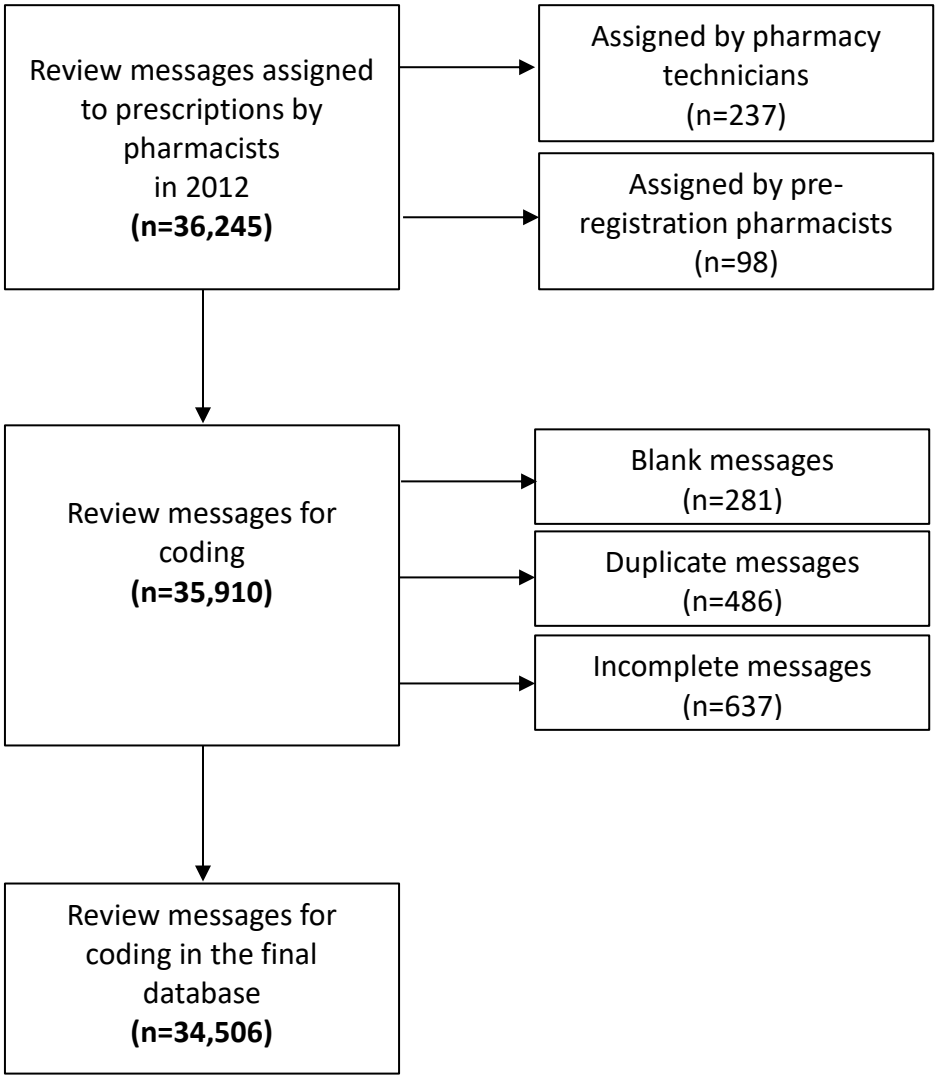


Figure 6.4 – Flow chart to show data that were excluded during the development of the database

Each of the factors coded are described below. The frequencies of review messages relating to each factor are summarised in Appendix 6.

6.3.1 Temporal factors

The majority of messages were assigned to prescription orders between Monday and Friday (98.6%, n=34,039/34,506). Nearly one quarter of these were assigned on a Monday alone (22.9%, n=7,899/34,506) and steadily declined over the weekdays to 17.8% (n=6,151/34,506) on a Friday (Figure 6.5). Overall, a larger proportion of messages were assigned in the morning between 00:00–13:00 hours (61.5%, n=21,238/34,506), compared to the afternoon between 13:00–23:59 (13,268/34,506).

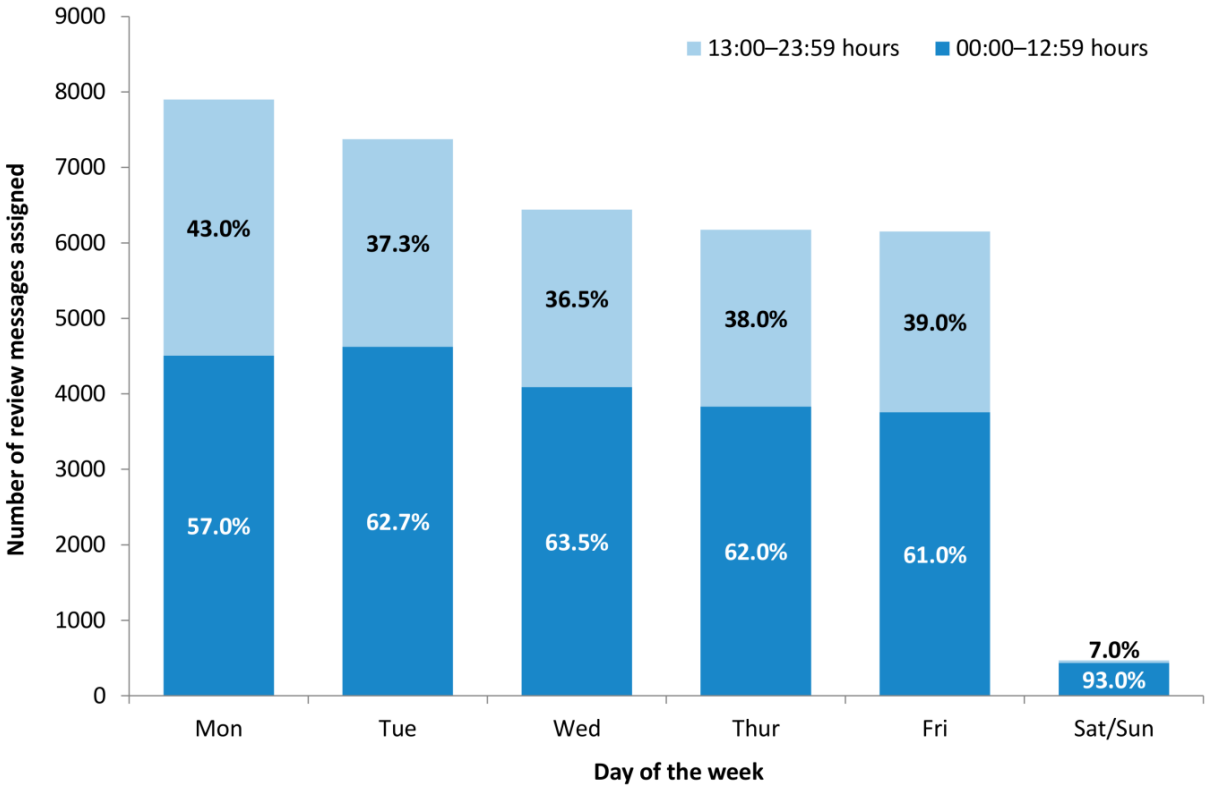


Figure 6.5 – Number of review messages assigned by pharmacists by day of the week and time of day

Peaks were observed in the assignment of messages at 10:00 (18.7%, n=6,436/34,506), 11:00 (17.8%, n=6,156/34,506) and 15:00 (10.8%, 3,712/34,506). The time of day messages were assigned was consistent across the days of the week, with peaks observed between 10:00–12:00 and 14:00–16:00 on a Monday to Friday and troughs around lunchtime at 13:00 (Figure 6.6). At the weekend, the majority of messages were assigned earlier in the day between 09:00–11:00.

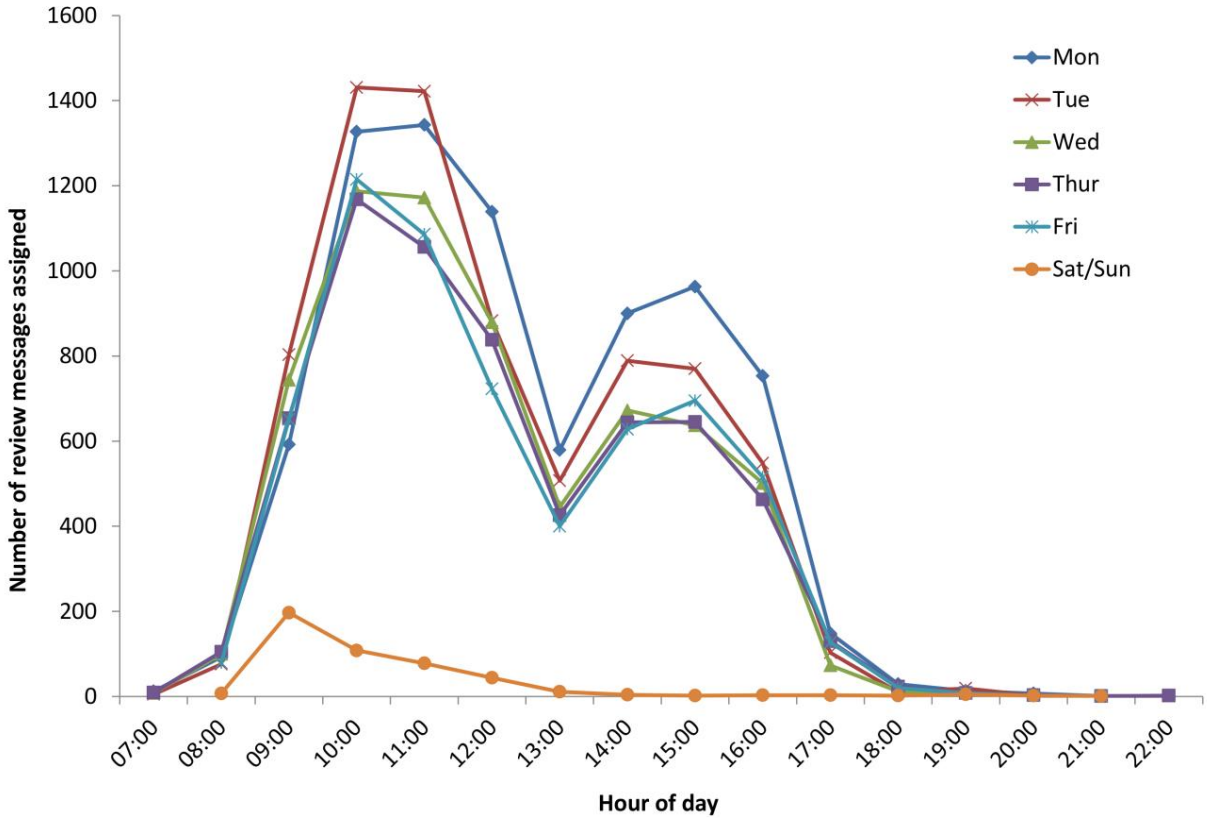


Figure 6.6 – Hour of day review messages were assigned across the days of the week
Excludes n=3 that occurred between 0:00–1:00 on a Tuesday and n=1 between 02:00–3:00 on a Friday.

Just over half of all the messages were assigned within the first 24 hours of the prescription being generated, with 25.8% within the first 12 hours (n=8,913/34,506) and 27.9% between 12–23:59 hours (n=9,636/34,506). A large proportion were then assigned within 1–6 days

of the prescription being initially generated (38.4%, n=13,278/34,506) and fewest assigned 7 or more days later (7.8%, n=2,679/34,506).

6.3.2 Message and prescription factors

6.3.2.1 Grade of the pharmacist

The 34,506 review messages were assigned to prescriptions by 55 different pharmacists identified though individual user logins—52 Full Time Equivalent (FTE) roles based on a 37.5 hour working week. Grade 7 pharmacists assigned the most messages overall (47.2%, n=16,302) and grade 8 the fewest (22.2%, n=7,672). Grade 7 pharmacists also assigned the most messages per FTE (Table 6.2).

Table 6.2 – Number of messages assigned by varying grades of pharmacist

Grade of pharmacist	No. of pharmacists	No. of FTEs	No. of review messages (%)	Number of messages per FTE pharmacist*
6	15	15	10,532 (30.5%)	702
7	20	19.24	16,302 (47.2%)	848
8	20	18.03	7,672 (22.2%)	426

*Rounded to the nearest whole number

6.3.2.2 Speciality

The majority of messages were assigned to prescriptions for patient's under the care of the Medical Specialities (29.8%, n=10,294/34,506) and General Medicine (8,429, n=8,429/34,506) and fewest for those under Critical Care and Burns (5.1%, n=1,744/34,506) (Table 6.3).

Table 6.3 – Number of messages assigned to patient's prescriptions by speciality

Speciality	No. of messages	Proportion of total no. of messages (%)
Medical Specialities	10294	29.8%
General Medicine	8429	24.4%
Medical Admissions	6663	19.3%
Surgical Specialities	3388	9.8%
General Surgery	2074	6.0%
Trauma and Orthopaedics	1914	5.5%
Critical Care and Burns	1744	5.1%
Total	***34506***	

6.3.2.3 Association with the prescription

On examination of the content of messages, 9.9% (n=3,406/34,506) were found to be unrelated to the prescription order on which they were assigned. This occurred most frequently for patients under the care of Medical Admissions (36.6% n=1,245/3,406), accounting for 18.5% of all the messages assigned in this speciality. Unrelated messages were assigned less frequently for those patients under Critical Care and Burns (1.4%, n=48/3,406), accounting for 2.8% of all those assigned in this speciality (Figure 6.7).

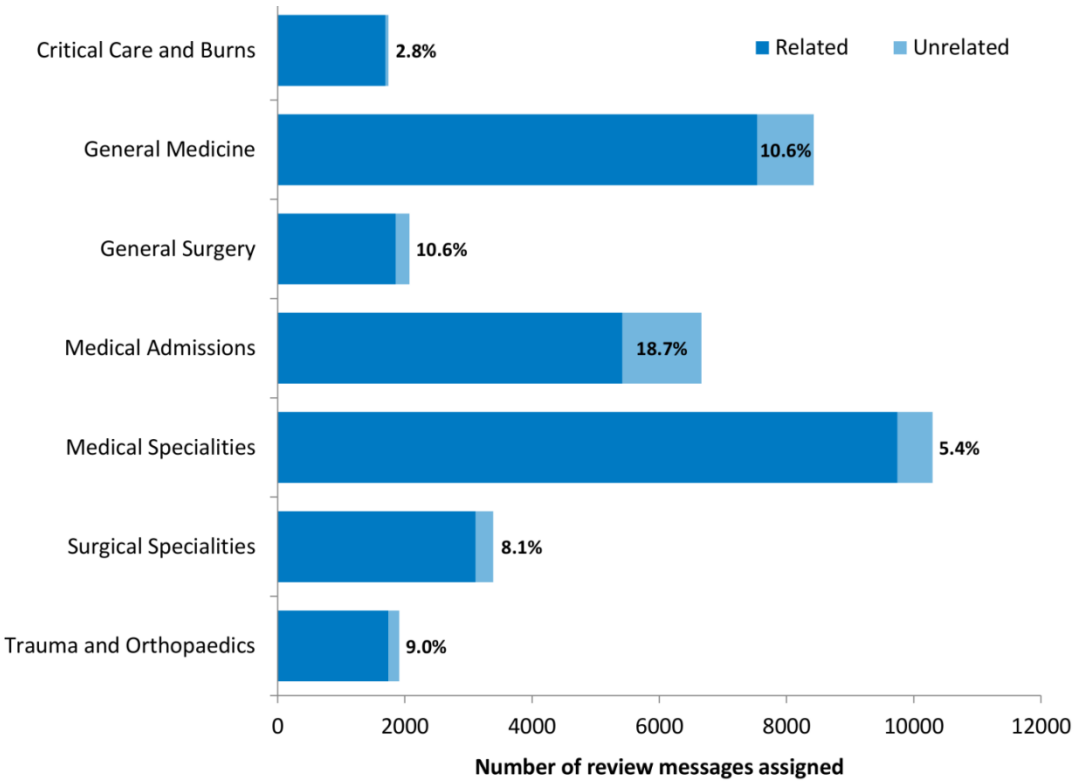


Figure 6.7 – Number of review messages assigned to prescription orders according to patient speciality and whether they were associated with the prescription

6.3.2.4 Medicine

Nearly half of all the messages (47.3%, 16,355/34,506) were assigned to two categories of medicines: Cardiovascular (24.5%, n=8,458/34,506) and the Central Nervous System (22.9%, n=7,897/34,506). This was still the case when only accounting for messages directly associated with the prescription (Figure 6.8). Fewer messages were assigned to medicines categorised as Other (e.g. acetylcysteine, n=46/83), Malignant Disease and Immunosuppression (e.g. Prograf®, n=38/218) and Skin (e.g. clotrimazole, n=97/342).

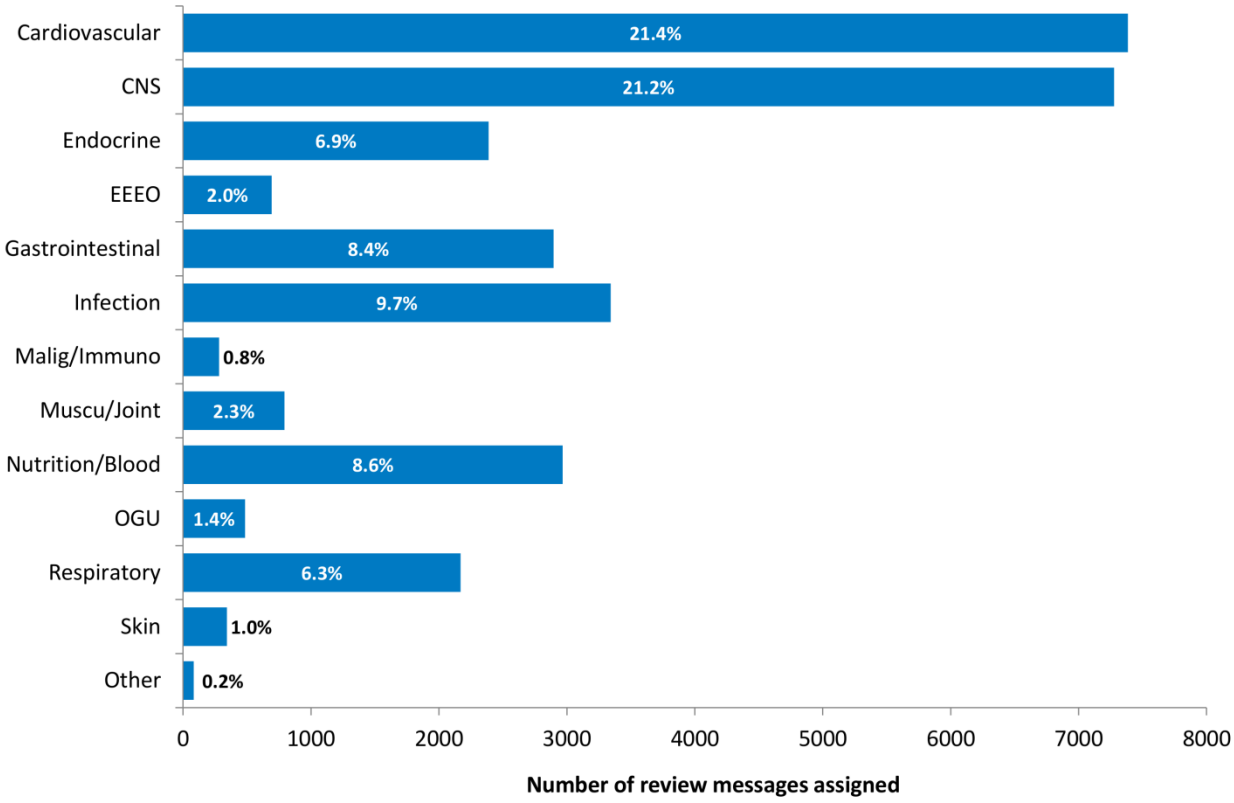


Figure 6.8 – Number of messages assigned to each category of medicine that were directly associated with the prescription

CNS Central Nervous System; EEEO Eye, Ear, Nose and Oropharynx; GI Gastrointestinal; Malign/Immuno Malignant Disease and Immunosuppression; Muscu/Joint; Musculoskeletal and Joint Disease; OGU Obstetrics, gynaecology and urinary-tract disorders

Just under one quarter of all the messages were assigned to ten different medicines in PICS (23.8%, n=8,227/34,506). The most common being enoxaparin (a Cardiovascular medicine), accounting for 6.3% (n=2,179/34,506) of all the messages (see Table 6.4), with one in every twenty prescriptions for enoxaparin having a message assigned in 2012 (4.9%, n=2,179/44,028). The second most common medicine was paracetamol (a Central Nervous System medicine), accounting for 3.1% of all the messages (n=1,075/34,506).

Table 6.4 – Top ten medicines with review messages assigned

Name of medicine	No. of review messages assigned	Proportion of total no. of messages (%)	Total no. of prescription orders in 2012	Proportion of total prescriptions with a message (%)
Enoxaparin	2179	6.3%	44,028	4.9%
Paracetamol	1075	3.1%	103,847	1.0%
Lansoprazole	890	2.6%	36,608	2.4%
Simvastatin	831	2.4%	20,869	4.0%
Aspirin	599	1.7%	33,024	1.8%
Adcal D3	559	1.6%	13,330	4.2%
Furosemide	544	1.6%	34,316	1.6%
Tramadol	541	1.6%	28,232	1.9%
Metformin	514	1.5%	10,734	4.8%
Codeine phosphate	495	1.4%	35,444	1.4%
Total	***8227***	***23.8***		

When considering only those messages that were directly associated with the prescription orders, the top four medicines remained the same (enoxaparin, paracetamol, lansoprazole, simvastatin), but aspirin and Adcal D3® no longer featured, replaced with Sando K® (an oral potassium chloride supplement) and lactulose (Table 6.5). For aspirin and Adcal D3®, 77.7% (n=262/337) and 46.7% (n=178/381) of all messages assigned to these medicines were not associated with the prescription respectively.

Table 6.5 – Top ten medicines with review messages assigned that were directly associated with the prescription order

Name of medicine	No. of review messages assigned	Proportion of total no. of messages (%)	Total no. of orders in 2012	Proportion of total prescriptions with a message (%)
Enoxaparin	2012	6.5%	44,028	4.6%
Paracetamol	977	3.1%	103,847	0.9%
Lansoprazole	814	2.6%	36,608	2.2%
Simvastatin	784	2.5%	20,869	3.8%
Tramadol	525	1.7%	28,232	1.9%
Furosemide	491	1.6%	34,316	1.4%
Metformin	483	1.6%	10,734	4.5%
Lactulose	465	1.5%	12,375	3.8%
Codeine phosphate	440	1.4%	35,444	1.2%
Sando-K	407	1.3%	12,083	3.4%
Total	***7398***	***23.8***		

*n=31,100 total number of review messages associated with the prescription

6.3.2.5 High-risk medicines

Almost a third of all messages were assigned to medicines considered high-risk (29.1%, n=10,047/34,506). In 93.0% of cases, the messages communicated information that was directly associated with that medicine (n=9,339/10,047). The majority of the messages were assigned to prescriptions for antibacterials (30.9%, n=3,102/10,047), followed by LMWHs (21.8%, 2,195/34,506) and opioid analgesics (21.6%, 2,175/34,506) (Figure 6.9)—an order that did not change when only considering related messages. In the year analysed, no messages were assigned to the Direct Oral Anticoagulants (DOACs).

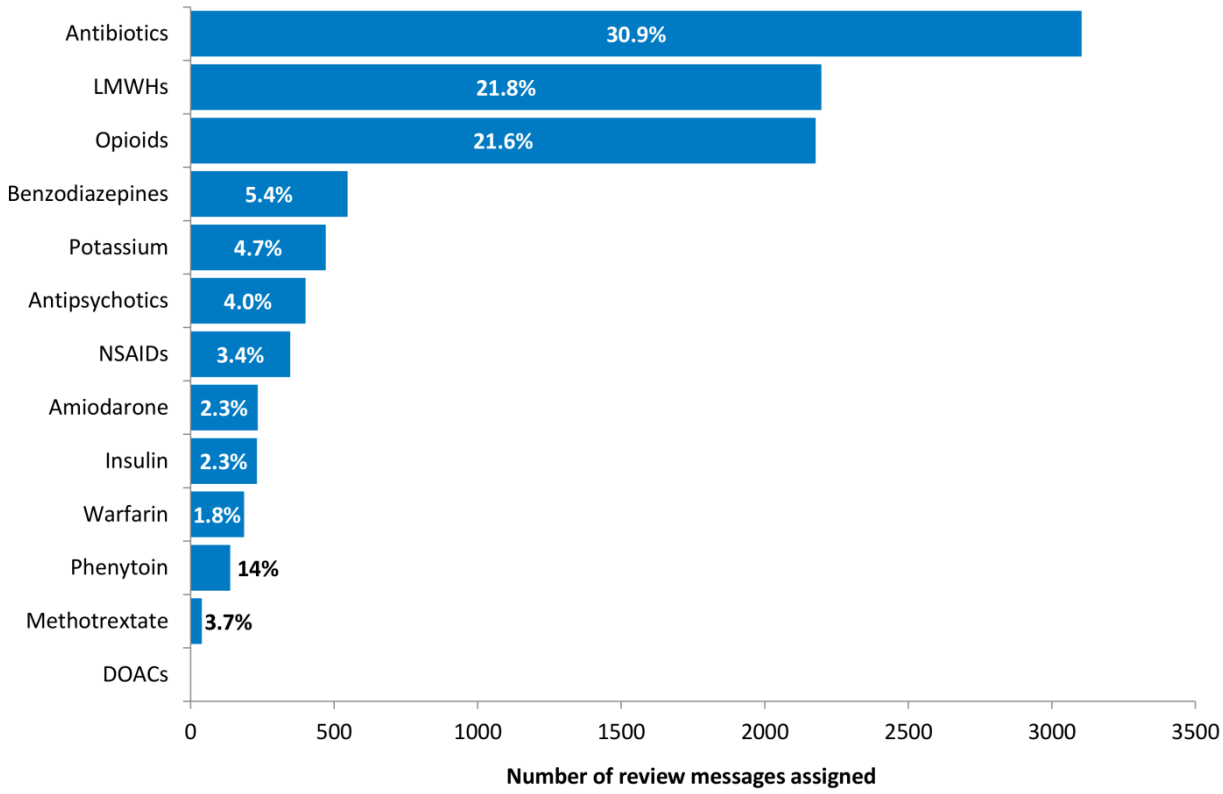


Figure 6.9 – Number of messages assigned to a high-risk medicine or class of medicine
DOACs Direct Oral Anticoagulants; NSAID Non-Steroidal Anti-Inflammatory Drugs; LMWHs Low Molecular Weight Heparins

6.3.2.6 Free-text prescription entry

The PICS system allows physicians to prescribe medicines that are not listed in the drug dictionary. So called 'dot drugs' because a dot (.) is added prior to writing the name of the medicine, the free-text nature of the entry overrides all associated CDS. Out of all the prescriptions analysed with a message assigned, 0.01% (n=364/34,506) were generated as a 'dot drug'. The majority of the messages highlighted to the physician that the 'medicine name had been prescribed to override all decision support' (18.7%, n=68/364) and to change this to a drug dictionary entry, for example: "*Aprepitant is in the PICS dictionary, please do not create a new drug*" [.apprepritant].

6.3.2.7 Regularity of prescription

Most messages were assigned to regular prescription orders (79.0%, n=27,276) (Figure 6.10) and fewest assigned to Once Only prescriptions (0.8%, n=266/34,506). Proportionally, fewer messages assigned to As Required prescriptions (3.4%, n=128/3,541) that were unrelated to the prescription. The most common medicine in this theme was lactulose (10.0%, n=367/3,669), with all messages assigned associated with the prescription.

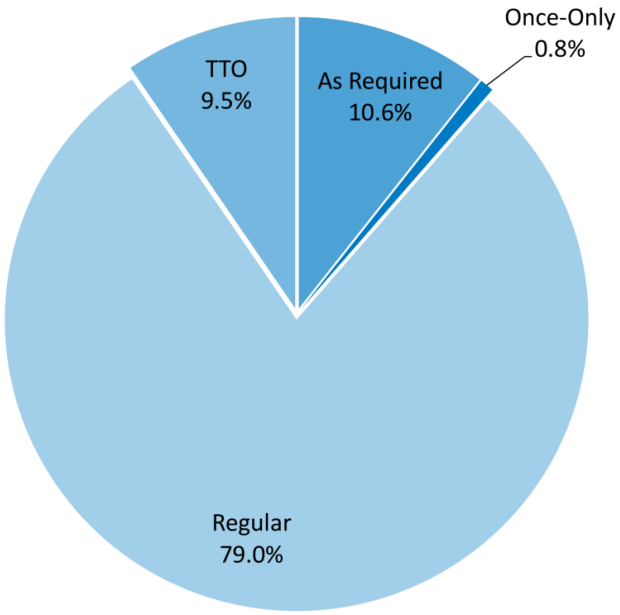


Figure 6.10 – Pie chart to show the regularity of the prescription orders on which messages were assigned

6.3.2.8 High-risk error

Overall, a small proportion of messages communicated information relating to one of the 80 high-risk errors identified in Chapter 4 and summarised in Appendix 3 (Thomas *et al.*, 2013) (3.8%, n=1,317/34,506). The majority were assigned by grade 7 pharmacists (45.7%, n=602/1,317) and fewest by grade 8 (16.3%, n=215/1,317). Of these 80, 45 were raised in a review message at least once. The most common high-risk error (Table 6.6), accounting for a quarter of all high-risk messages was, 'Paracetamol prescribed at a dose of 4 g over a 24

hour to a patient under 50 kg' (26.6%, n=350/1,317). Proportionally, more messages related to a high-risk error in General Medicine (5.4%, 458/8,429) and fewest in Medical Admissions (2.1%, n=143/6,663). Appendix 7 provides a summary of all high-risk errors and the frequency at which these were communicated.

Table 6.6 – Most common high-risk errors communicated via the review message

Prescribing indicator of high risk-error	No. of messages	Proportion assigned to medicine (%)
Paracetamol prescribed at a dose of 4 g over a 24 hour to a patient under 50 kg *(Risk of hepatocellular toxicity)*	350	32.2
Statin prescribed concomitantly with a macrolide antibiotic *(Increased risk of myopathy)*	203	24.4
Low molecular weight heparin prescribed to a patient with renal impairment without dose adjustment *(Increased risk of bleeding)*	156	7.1
Potassium chloride supplements continued for longer than is required (reference range 3.5–5.3 mmol/litre) *(Increased risk of hyperkalaemia)*	139	29.6
Nitrofurantoin prescribed to a patient with eGFR < 60* ml/minute/1.73m^2 *(Risk of peripheral neuropathy and inadequate concentration in urine)*	102	57.6
Total	***950***	
Total number of high-risk medicines	***1,317***	

*60 ml/minute/1.73m^2 was the recommended limit at the time of the study

6.3.2.9 Medicines reconciliation

Nearly half of all messages communicated information relating to the reconciliation process—comparing the patient's current treatment regimen to that taken prior to admission (44.3%, n=15,295). The majority of these were assigned to patients under Medical Admissions (33.9%, n=5,180/15,295) (Figure 6.11). Very few messages were

assigned by pharmacists at the weekend that related to this process (0.4%, 67/15,295) (Figure 6.12).

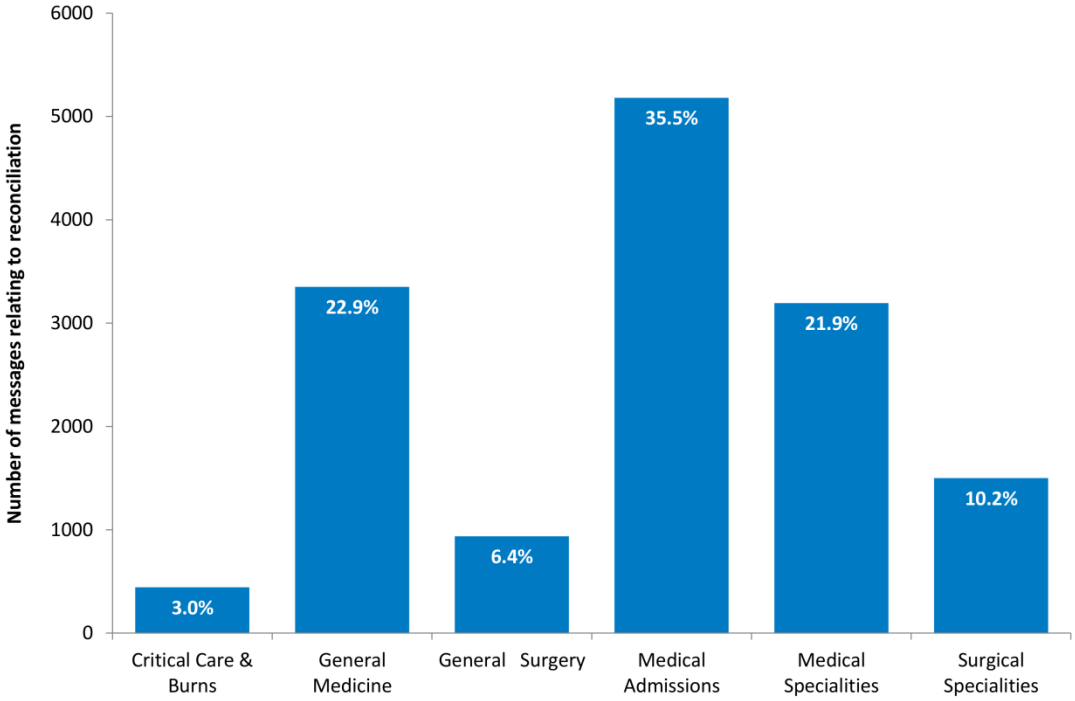


Figure 6.11 – Messages relating to the medicines reconciliation process in each speciality

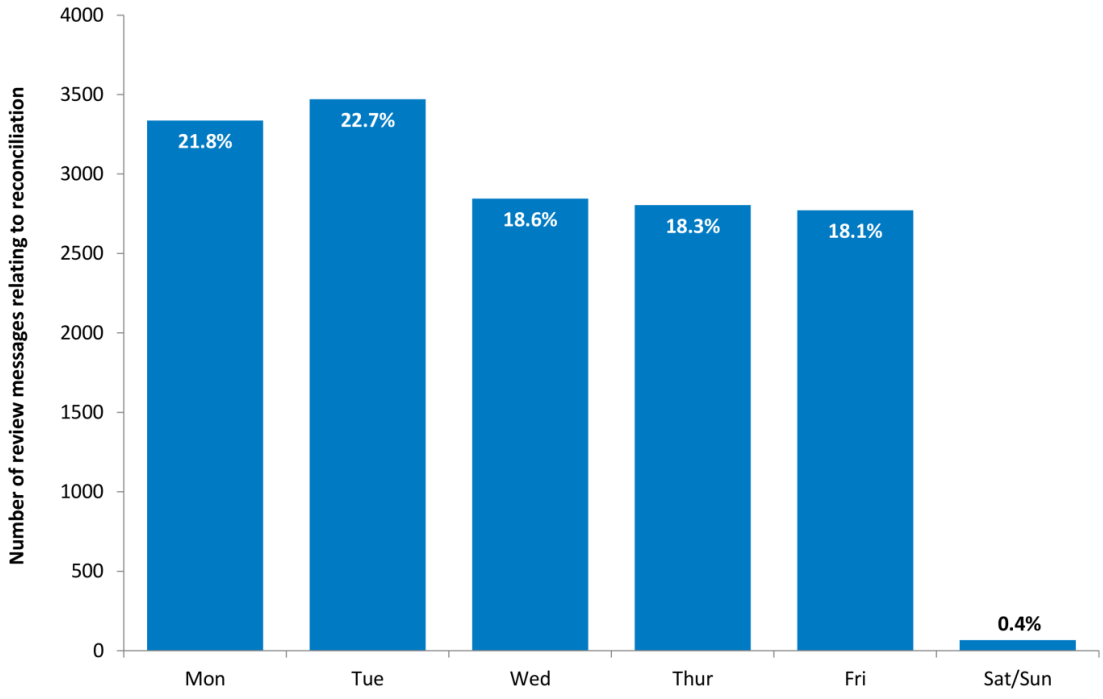


Figure 6.12 – Messages relating to the reconciliation process by day of the week

Table 6.7 summarises the times taken to assign the messages, the majority of which were assigned within 24 hours (60.8%, n=9,301/15,295).

Table 6.7 – Time since the prescription was generated and message relating to reconciliation assigned

Time from prescription generated to message assigned	No. of reconciliation messages	Proportion of total messages (%)
< 12 hours	4070	26.6%
12:00–23:59	5231	34.2%
1–6 days	5559	36.3%
7+ days	435	2.8%
Total	***15295***	

6.3.2.10 Theme of communication

The analysis of the content of messages identified 129 topics of communication, categorised into ten themes (Chapter 5). The most common theme of communication related to the Dose/Frequency (27.1%, n=9,361/34,506), followed by the provision of Supporting Information (23.0%, n=7,953/34,506) and then Drug Use/Administration (13.9%, n=4,790/34,506) (Figure 6.13). Messages raising the logistics of the prescription order were least frequent (0.02%, n=622/34,506). Appendix 8 provides a summary of the number of messages within each of the 129 topics.

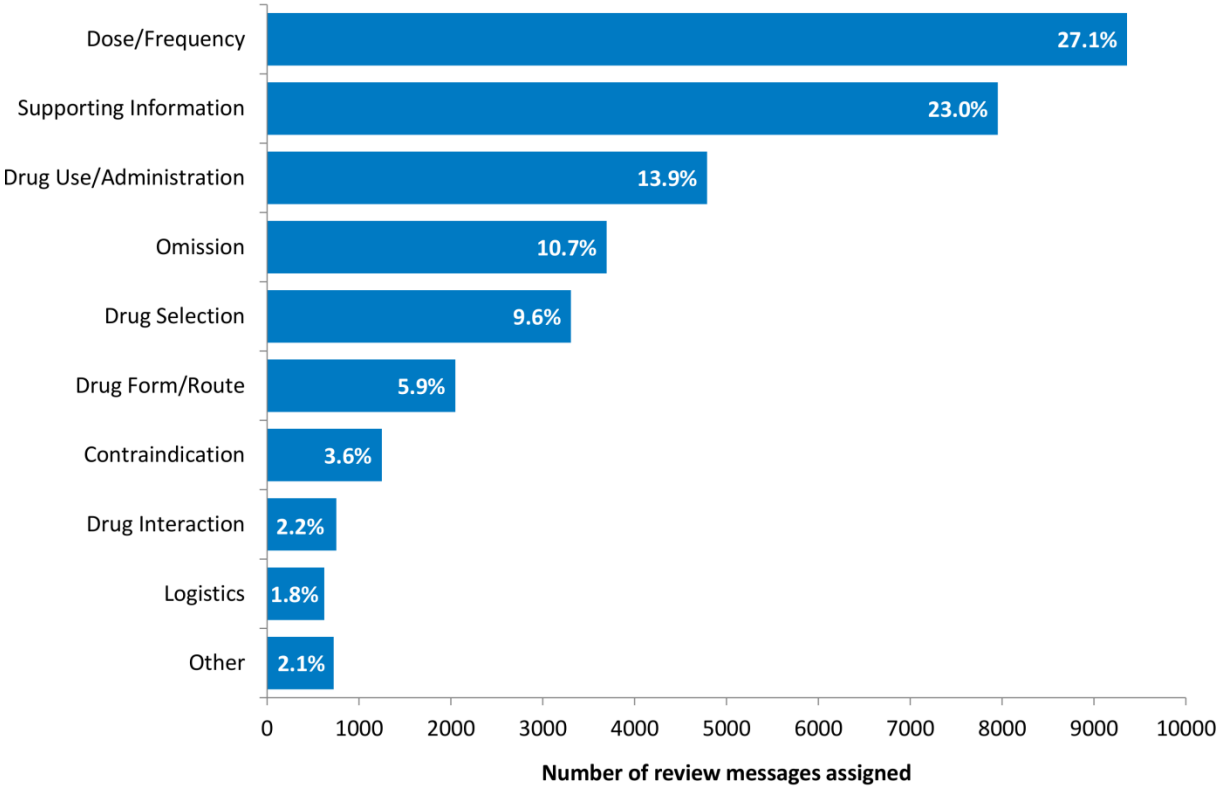


Figure 6.13 – Number of review messages assigned to prescription orders by the theme of communication

Looking at the grades of the pharmacists assigning the messages, those of grade 7 (n=20) assigned a higher proportion within each category compared to grade 8 (n=20) (see Table 6.2). The category where this was most prominent were messages relating to Omissions, with 54.2% (n=2,003/3,696) assigned by grade 7, compared to 8.2% (n=304/3,696) by grade 8 (Figure 6.14).

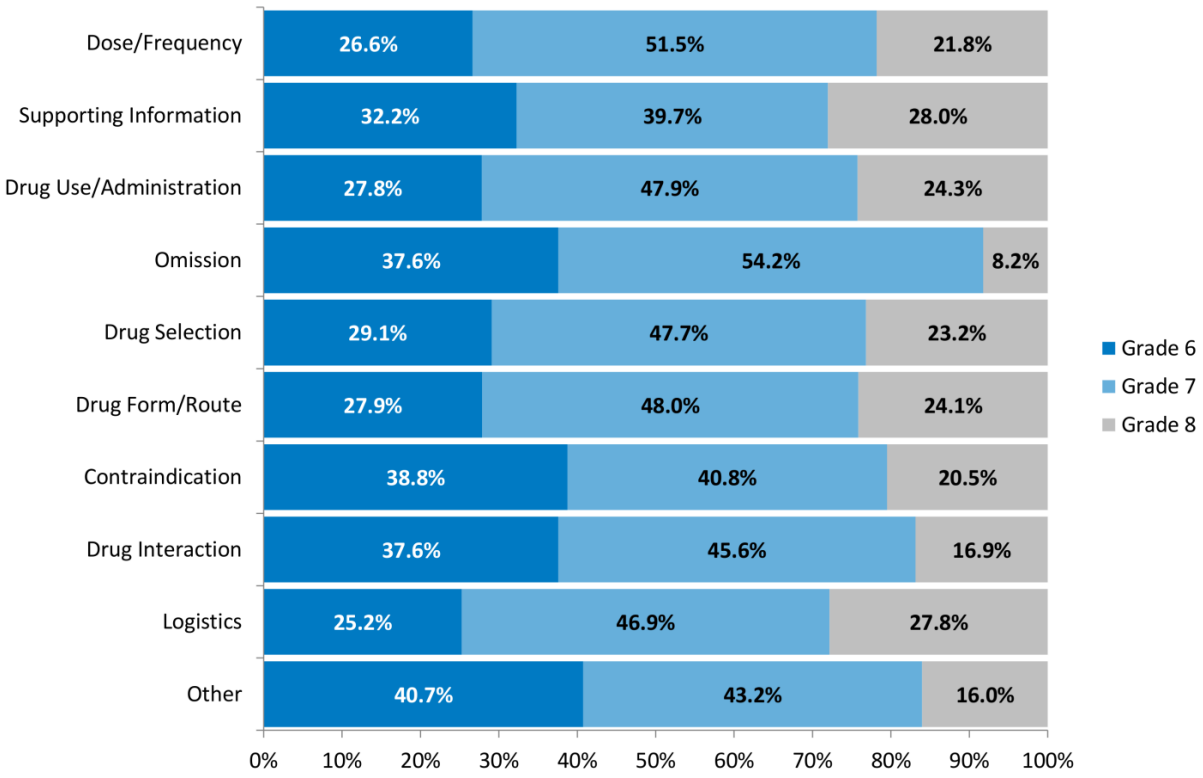


Figure 6.14 – Proportion of messages by theme assigned by grade of pharmacist

All themes of communications occurred across all specialities. Looking at the proportions for each theme across specialities (Figure 6.15), messages relating to Dose/Frequency and Omissions stand out in the Medical Admissions compared to any other speciality (25.6%, n=2,401/9,361; and 36.1%, 1,336/3,696), as well as Drug Interactions in General Medicine (40.4%, n=304/753).

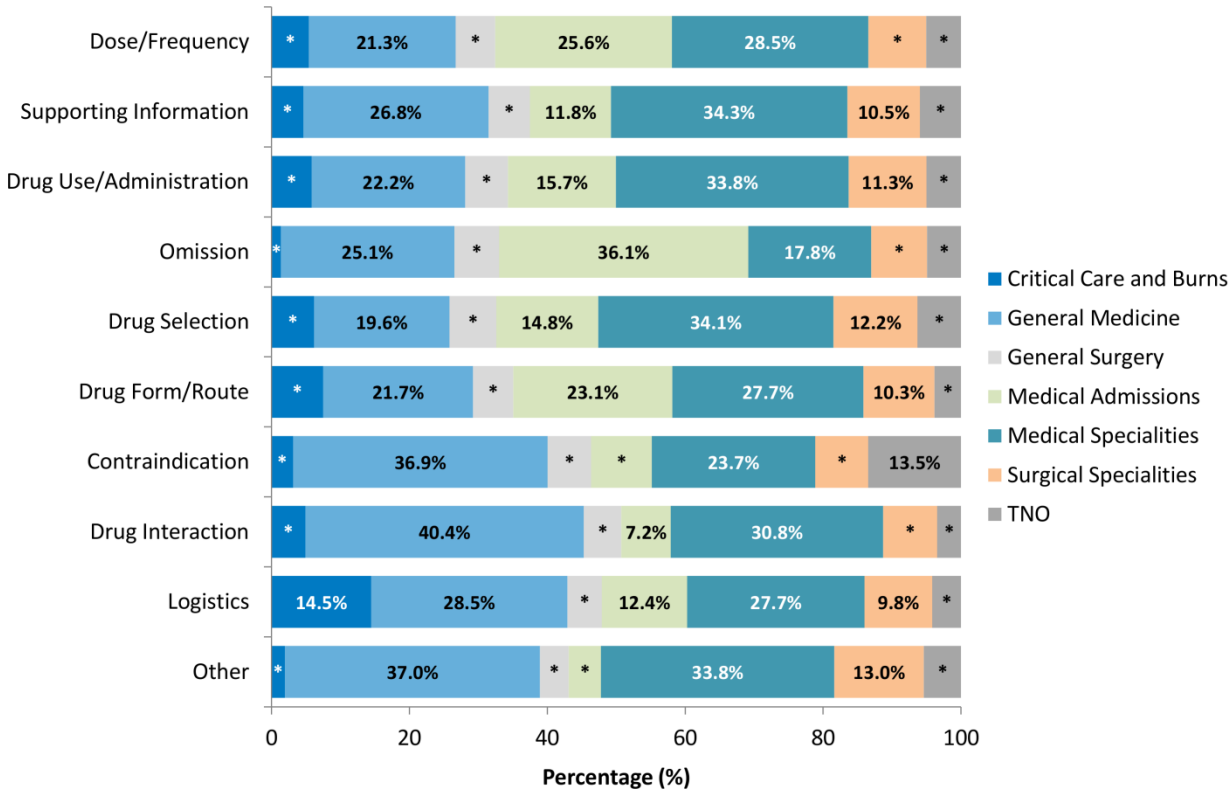


Figure 6.15 – Proportion of messages by each theme assigned to prescriptions in specialities
*<10% of messages

The top ten topics of communication accounted for 44.8% of all the messages (Table 6.8). The most frequent was to provide information about a patient's usual 'at home' dosing regimen (10.5%, n=3,638/34,506). The second most common related to an omission of treatment, specifically one previously taken by the patients and not reflected on their

current hospital prescription (8.2%, n=2,828/34,506). The most frequent topics are listed in order in Table 6.8, along with the most common medicines with a message assigned.

Table 6.8 – Top ten topics of communication and the most common medicines within each topic

Topic of communication	Theme of communication	No. of messages	Proportion of messages in theme (%)	Proportion of all messages (%)	Most common medicines	Proportion of messages in topic (%)
Information is provided on the patient's usual dosing regimen (no change requested)	Supporting Information	3638	45.7%	10.5%	Lansoprazole Furosemide Simvastatin Adcal D3	4.3% 3.9% 3.5% 3.5%
There is an omission according to the patient's medication history	Omission	2820	76.3%	8.2%	Aspirin Adcal D3 Enoxaparin Amlodipine	8.1% 5.5% 5.3% 3.5%
The dose is too low compared to pre-admission	Dose/ Frequency	1781	19.0%	5.2%	Levothyroxine Furosemide Clenil Modulite Atorvastatin	4.8% 3.8% 3.3% 3.3%
The dose is too high	Dose/ Frequency	1358	14.5%	3.9%	Paracetamol Enoxaparin Domperidone Co-codamol 30/500	27.7% 24.2% 3.5% 2.0%
The frequency is too low	Dose/ Frequency	1052	11.2%	3.0%	Lactulose Enoxaparin Laxido (macrogol) Meropenem	36.1% 4.0% 3.5% 2.9%

Topic of communication	Theme of communication	No. of messages	Proportion of messages in theme (%)	Proportion of all messages (%)	Most common medicines	Proportion of messages in topic (%)
A duration is needed on the prescription	Drug Use/ Administration	1041	21.9%	3.0%	Sando-K Amiodarone Co-amoxiclav Chloramphenicol Eye Drops	13.0% 9.3% 6.5% 5.2%
The duration of treatment requires review	Drug Use/ Administration	1036	21.6%	3.0%	Enoxaparin Dexamethasone Nitrofurantoin Sando-K	10.6% 5.0% 3.6% 3.1%
The dose is too low	Dose/ Frequency	1029	11.0%	3.0%	Enoxaparin Vitamin B/C IV Vancomycin Paracetamol	35.0% 8.3% 3.9% 3.3%
The dose is too high compared to pre-admission	Dose/ Frequency	906	9.7%	2.6%	Simvastatin Lansoprazole Levothyroxine Amitriptyline	12.7% 9.7% 5.0% 3.6%
There is a duplicate prescription with a medicine of the same class	Drug Use/ Administration	812	17.0%	2.4%	Tramadol Codeine phosphate Ranitidine Morphine sulfate oral solution	20.4% 10.2% 9.9% 5.8%
	Total	**15473**		**44.8%**		

IV Intravenous

Dose/Frequency messages

The Dose/Frequency theme was most commonly associated with communications relating to the medicines reconciliation process (28.0%, n=4,276/15,296) and the majority related directly to the prescription on which they were assigned (99.7%, n=9,336/9,361). The most frequent Dose/Frequency topic related to a dose error perceived to be lower than that usually taken by the patient (19.0%, n=1,781/9,361)—assigned to 263 different medicines in PICS, with levothyroxine the most common (4.8%, n=86/1,781). Messages relating to perceived errors of the dose or frequency being too high or low accounted for 85.3% of all communications in this theme (n=7,982/9,361) (see Appendix 8). The most common medicines with Dose/Frequency problems identified and highlighted with a message were for enoxaparin (8.7%, n=811/9,361), paracetamol (5.8%, 548/9,361), lactulose (4.3%, 406/9,361) and simvastatin (2.1%, 197/9,361). For enoxaparin, the majority of messages highlighted a dose that was too low (16.5%, n=360/2179) or too high (15.1%, n=329/2179); for paracetamol the dose being too high (35.0%, n=380/1,086); for lactulose the frequency being too low (80.0%, n=380/475); and for simvastatin the dose being higher than that usually taken by the patient (13.8%, 115/831).

Supporting information

The most common Supporting Information message was to provide information about a patient's usual regimen, accounting for almost half of these messages (45.7%, n=3,638/7,953). For example, "*dhx = 2 mg bd*" [dhx being an abbreviation for the drug history, followed by the dosing schedule of twice a day). The second most frequent topic provided information about the usual dosing regimen for a medicine (7.9%, n=629/7,953), for example: *"Usually given 12-hourly"* on a prescription for intravenous ondansetron. A

proportion of these messages requested that various parameters were monitored (8.7%, n=692/7,953), for example *"Monitor potassium please",* assigned to a prescription for an oral formulation of potassium chloride.

Drug Use/Administration

The most frequent topic relating to the Drug Use/Administration process was to request that a duration of treatment was added to the prescription order (21.7%, n=1,041/4,790). This was most frequent on prescriptions for Sando-K (13.0%, 135/1,041), for example: "*Please specify end date*". The second most common topic was to request a review of the duration of treatment (21.6%, n=1,036/4,790), which was mostly frequently assigned to enoxaparin prescriptions (10.6%, n=110/1,036). For example: *"Please review if still required as INR* [International Normalised Ratio] *is now within range".*

Omission

Messages relating to an omission of treatment accounted for 10.5% (n=3,661/34,506) of all messages. The majority of these messages (86.3%, n=3191/3,696) were unrelated to the prescription on which they are assigned. An omission of treatment on admission to hospital was the most common topic communicated in this theme (88.4%, n=2,830/3,191). These were mostly sent by grade 6 pharmacists, with 75 messages per pharmacist per annum (40.0%, n=1128/2820,) and grade 7, with 77 messages per pharmacist per annum (54.7%, n=1543/149). Grade 8 pharmacists assigned few messages relating to this type of omission, with only 7 messages per pharmacist per annum (5.3%, n=149/2,820).

An analysis of the medicines with messages assigned relating to omission showed that 47.3% (n=1,749/n=3,696) began with letters A to C in the alphabet, appearing first on a patient's prescription profile as these are listed alphabetically on screen. Out of the 505 Omission messages that did relate to the prescription, the most frequent was to raise that a patient was on a combination preparation but only a single component had been prescribed (65.0%, n=328/505). A third of these were assigned to Adcal (32.6%, n=107/328) and highlighted to the physician that a combination with vitamin D is usually taken by the patient: "*Patient takes Adcal D3 two daily - please change"*.

Drug selection

The most common topic within the theme of Drug Selection was to highlight that a duplicate medicine had been prescribed in light of an existing class of medicine (n=24.5%, 812/3,308). This occurred most frequently with tramadol (20.4%, n=166/812) and codeine phosphate (10.3%, n=83/812). For example: *"Patient also on morphine, please rationalise"* assigned to a regular prescription for tramadol. The second most common topic was to highlight to the physician that the patient takes a different class of medicine to that which has been prescribed (18.4%, n=608/3,308). This occurred most frequently with lansoprazole (31.1%, n=189/608), followed by simvastatin (15.5%, n=94/608). A small number of messages related to CPOE selection errors (n=11/34,506), assigned on nine different medicines. For example, the prescription of 'clonazepam' when the pharmacist perceived that 'clobazam' may be intended (n=2/11).

Drug Form/Route

The most common topic within the theme of Drug Form/Route was to request a change from a standard-release formulation to a modified-release formulation to be consistent with the patient's usual regimen (34.1%, n=699/2,050). This occurred most frequently on prescriptions for metformin (18.0%, n=126/699), followed by doxazosin (9%, n=63/699). For example: "*Patient normally takes MR tablets - please change*" on a prescription for metformin. The second most common was to request a change in the formulation of a medicine from a solid dosage form to a liquid or dispersible form (14.6%, n=299/2,050). This occurred most frequently on prescriptions for lansoprazole (17%, n=51/299) and paracetamol (10.7%, n=32/299).

Contraindication

Messages relating to a Contraindication accounted for 3.6% (n=1,249/34,506) of all the messages. The majority of these related to a drug-disease interaction, with the medicine prescribed increasing the risk of falls (46.4%, n=580/1,249) and the pharmacist asking for a review in light of this. For example: *"Patient has a falls risk. Please consider using a less sedating antihistamine"*, assigned to a prescription for chlorphenamine. This message type was most frequently assigned to the opioid analgesics codeine phosphate (25.2%, n=146/580) and tramadol (17.2%, n=100/580). The second most common topic within this theme related to drug-disease interactions as a result of patient comorbidities (26.3%, 328/1,249). These were mostly assigned to nitrofurantoin (30.8%, n=101/328), raising a contraindication with the patient's level of renal function and the need to select an alternative antibiotic: "*Please review, eGFR* [glomerular filtration rate] *<60 ml/minute. Nitrofurantoin ineffective because of inadequate urine concentrations. Consider switching to*

trimethoprim 200 mg BD [twice a day] for three days". The remaining messages were assigned to 81 different medicines, with the second most frequent being enoxaparin (5.5%, n=18/328).

Drug Interaction

Messages highlighting a drug interaction accounted for 21.8% of the messages (n=753/34,506). The majority of these related to a pharmacokinetic interaction (n=74.8%, 563/753), with the absorption, distribution, metabolism or excretion of one of the 83 medicines affected by the concomitant treatment. These messages were most commonly assigned to simvastatin (44.5%, n=251/563) and clarithromycin (7.8%, n=44/563) and in both cases the same interaction was raised: "*Interaction between simvastatin and clarithromycin increased risk of myopathy. Please consider pausing the simvastatin until course of clarithromycin is complete*". Messages relating to a pharmacodynamic interactions —identifying synergistic or antagonistic effects or adverse effects—were assigned to 59 different medicines (25.2%, n=190/753), the most common being tramadol (14.7%, n=28/190) and ibuprofen (12.6%, n=24/190).

Logistics

Messages relating to the logistics of the prescription accounted for 1.8% of all the messages (n=622/34,506), the smallest proportion overall. The most common topic within this theme was for the pharmacist to inform the physician that the medicine was not stocked in the hospital and requested for an alternative to prescribed (74.1%, n=461/622). These messages were assigned to 195 different medicines. The second most common topic also

related to stock of a medicine, but as a result of manufacturing delays as opposed to stock held by the pharmacy department (9.5%, n=59/622).

Other

The most common topic of communication coded as 'Other' related to an out-of-date discharge summary, with 68.5% (n=496/724) of requests asking for the TTO to be updated to reflect the inpatient regimen. The second most common topic was to raise the use of a 'dot drug' to generate the prescription (n=9.9%, n=72/724). This shows that out of the 364 'dot drug' prescriptions in the database, not all of them were identified by the pharmacist as a problem (see section 6.3.2.6, *Free-text drug entry*).

6.2.2.11 Length of messages

The maximum length of any review message assigned in PICS is 255 characters. Overall, pharmacist's messages contained a median of 45 characters (Interquartile range (IQR) 30–68). A post-hoc analysis found there was a significant difference in the median length of messages across the grades of pharmacists ($p<0.001$) (Table 6.9). A pair-wise comparison showed a significant difference between grade 6 and 8 pharmacists ($p<0.001$) and grade 7 and 8 pharmacists, with grade 8 pharmacists assigned shorter messages overall. There was no difference between grade 6 and 7 pharmacists ($p=0.738$).

Table 6.9 – Median length of review messages assigned by grade of pharmacist

Grade of pharmacist	Median no. of characters	Interquartile range
6	47	29–72
7	46	32–67
8	40	27–64

There was also a significant difference in the length of the review messages across the themes of communication ($p<0.001$) (Table 6.10).

Table 6.10 – Median length of review messages by theme of communication

Theme of communication	Median no. of characters	Interquartile range
Drug Interaction	72	53–96
Logistics	61	42–87
Contraindication	57	37–82
Omission	57	40–78
Drug Selection	50	35–72
Dose/Frequency	46	35–64
Drug use/Administration	43	27–65
Drug Form/Route	42	28–59
Other	36	18–59
Supporting Information	34	20–58

Messages communicating information about a Drug Interaction had the highest median length of 72 characters (IQR 53–96), compared to Supporting Information with a median length of 34 characters (IQR 20–58).

6.3 Discussion

In this study, 34,506 free-text review messages were analysed for their content, along with the associated prescriptions on which they were assigned. Between 2009 and 2014, there was a year-on-year increase in the pharmacists' use of the review message function. Albeit

small (0.2 percentage points per annum), it may suggest an increasing dependence on the modality of communication over time. On the other hand, the increase observed may be due to an increasing workload from the increasing number of inpatient episodes each year at the hospital, increasing number of medicines prescribed in the NHS (Health and Social Care Information Centre, 2016) and increasing roles such as medication history taking and medicines reconciliation. In addition, pharmacists are taking on many more clinical tasks during the medication review process, such as with completing assessments to identify any medicines that may increase the risk of patient falls (National Institute for Health and Care Excellence, 2013). A function to communicate information quickly and in a manner that is not dependent on the presence of the recipient may be selected to help manage workload, since it may decrease the time to complete a task. Alternatively electronic communication may be used as a means to avoid challenging the physician directly about medication-related problems (Liu *et al.*, 2014).

The majority of messages were assigned by pharmacists between a Monday and a Friday, highlighting the reduction in clinical pharmacy services over a weekend at the study site and possibly explaining the slightly higher proportion of messages assigned at the beginning of the working week. The activity of pharmacists in identifying potential drug-related problems during the week may serve as evidence for implementation of seven day pharmacy services in the hospital setting. Patient admissions do not stop over the weekend and although the rates of admission may be slightly lower during this time, evidence also suggests that patients are sicker and are at higher risk of death and readmission to hospital if admitted on a Saturday or Sunday (Freemantle *et al.*, 2015). On-going review of patients' medications is essential for safe optimal patient care. This would require a transformation

of acute hospital services, which includes seven day working so that medication review and reconciliation can continue throughout the week (Office of the Chief Pharmaceutical Officer, 2016).

The messages within PICS are restricted to 255 characters and although this may seem short to communicate medication-related information, pharmacists rarely used the allocated space. Messages were found to have a median length of just 45 characters, a quarter of the maximum length in PICS and even half that of the Tweet length recommended by Twitter for maximal value and engagement (Lee, 2014). Grade 8 pharmacists assigned shorter messages overall and messages relating to a drug interaction were longer than any other theme—likely because the pharmacist needs to state the name of two or more medicines to explain the interaction. The consistent practice of assigning relatively short messages may be reflective of an increasing workload, with short messages used to save time in the long-run. It cannot be determined from this study whether this impacts on the interpretation of the messages by the physician and overall effectiveness of the communication.

A large proportion of the messages related to the medicines reconciliation process and the true number is likely to be higher than that found given that the messages were coded based on an explicit statement from the pharmacist that the query or request related to the patient's pre-admission regimen. In contrast to other UK studies that show errors of omission to occur most frequently in this process (De Winter *et al.*, 2010; Quélennec *et al.*, 2013; Urban *et al.*, 2014), communications relating to the Dose/Frequency were most prevalent in this study. The PICS CPOE system does not have a function to facilitate the medicines reconciliation process (e.g. integrated with community records, documentation

of discrepancies), so information and queries relating to this process need to be communicated to the physician via a review message or other means. Programmes to assist the process have been shown to reduce the rate of discrepancies in the hospital settings (Zoni *et al.*, 2012), but this technical capability is not one considered by many hospitals at system implementation, rather as an enhanced function as systems mature (NHS England, 2013). The frequency of these messages may highlight the difficulties faced by practitioners in determining a patient's medication history on admission to hospital, largely as a result of poor or lack of sharing of information at the interface of care. The time required to gather the necessary information from different sectors of care has been shown to be a barrier for effective reconciliation, as well as poor communication and documentation between and by teams relating to this task (Ross *et al.*, 2013). The study by Ross *et al* (2013) also found that these problems persisted when physicians discharged patients. Although this was not a prominent theme in the messages in this study, such discrepancies at discharge are likely to be dealt with directly to avoid any delays in the process and as such would not be reflected in the database. The majority of reconciliation messages were assigned between a Monday and a Friday—reflective of little or no ward-based reconciliation activity at the weekend—and were mostly made in the Medical Admissions department. Nearly two thirds of all reconciliation messages were assigned within 24 hours of the prescription being generated and thus adhered to the national standard (National Institute for Health and Care Excellence, 2015). Medical Admissions could be an initial target for weekend services to achieve a timelier reconciliation process overall.

Pharmacists communicated a range of medication-related information to the physician. The most common theme related to the Dose/Frequency of a medicine, many of which

could be considered prescribing errors by definition (Dean *et al.*, 2000). Although the frequency of communications cannot be extrapolated to a rate of error *per se*, the high prevalence of perceived dose and frequency errors observed is consistent with other UK studies investigating prescribing errors in the hospital setting (Dornan *et al.*, 2009; Tully *et al.*, 2009). Messages relating to Dose/Frequency were most commonly assigned to enoxaparin, paracetamol, lactulose and simvastatin—four frequently prescribed medicines in the acute NHS sector. For enoxaparin, paracetamol and lactulose, messages largely related to the dose or frequency being too low or too high (unrelated to the reconciliation process) and so are most likely to be knowledge-based mistakes (Reason, 1990; p 13). This may highlight an area within the system where CDS can be optimised to better guide physicians through the prescribing process. For simvastatin, the Dose/Frequency errors were largely as a result of a discrepancy compared to pre-admission regimens. This may further highlight how a lack of information to inform the medication history can lead to knowledge-based mistakes, perhaps with a potential to encourage physicians to prescribe the most common dose until the information can be confirmed.

Pharmacists used the review message function to provide a lot of supporting information—evidence that it is used for far more than requests for review. In paper-based prescribing environments, pharmacists can annotate prescriptions to provide additional information to facilitate the medication process, such as with requests to monitor treatment (Liu *et al.*, 2014). In the electronic prescribing environment, such written annotations are not possible, or annotations may be restricted and not easily added. The number of these messages still being communicated in this way may suggest sub-optimal design to align with practice. Pharmacists may be accustomed to the process of annotating paper drug charts and so use

workarounds in the system to ensure that this is still possible in order to fulfil a professional standard outlined by the Royal Pharmaceutical Society for hospital pharmacy services, *"Care contributions are documented and audited to demonstrate the impact of the service on patient outcomes and to help target resources"* (Royal Pharmaceutical Society, 2012). Most CPOE systems provide information about monitoring and some complex systems such as PICS are even integrated with laboratory data to drive patient specific decision support. The continued provision of this information in a highly computerised environment may highlight a lack of pharmacists' knowledge in relation to CDS, such as which alerts are presented to physicians at the point of prescribing and review. Alternatively, it may show a lack of confidence in the CDS to effectively inform physicians about monitoring requirements, possibly because pharmacists are aware of the propensity for alerts to be overridden (McMullen *et al.*, 2015; van der Sijs *et al.*, 2010).

Looking at the prevalence of messages by topic, informing the physician about a patient's usual regimen, without asking for a direct change or review, was the most common topic out of all the messages. The provision of information without a recommendation may indicate that the pharmacist is seeking clarification, although CPOE has previously been shown to reduce these types of queries with physicians in the hospital setting (McMullen *et al.*, 2015). Alternatively, pharmacists may be using the review message function to document the information for accountability and to make the information visible to all members of the healthcare team involved with the medication process. Perceived errors of omission were the second most common topic and most common if those coded as supporting information are removed. This is consistent with UK studies investigating medication prescribing errors (Dornan *et al.*, 2009; Tully & Buchan, 2009) or medication-

related patient safety incidents (Cousins *et al.*, 2012), where errors of omission are generally observed the most. The design of the review message function in PICS—to assign a message directly to a prescription—does not support an optimal communication for errors of omission, since the medicine in question is not present on a patient's profile. Prescriptions are listed alphabetically in PICS and the data in this study suggests that the messages were largely placed on medicines towards the top of the list (A–C in the alphabet), unrelated to the prescription. This highlights the use of a workaround within the CPOE system, with the pharmacist finding a way of documenting the information electronically to fulfil a communication and complete a task. Such workarounds can be important to inform system design (Cresswell *et al.*, 2016).

Although a few CPOE-related errors were identified as a result of 'selection errors', it was not apparent from the data whether communications were sent as a direct result of sociotechnical incidents. This is difficult to determine with content analysis since it is dependent on the pharmacist stating that the problem identified may relate directly to the use of the system. A study conducted in the same hospital site—one year prior to this database being captured—found that 15% of medication incidents occurred as a result of sociotechnical issues (Redwood *et al.*, 2011). To capture a more realistic rate of error and as a means of being able to monitor such incidents, pharmacists could be asked to make it explicitly clear in their communications when a sociotechnical incident is suspected. Alternatively, a tick-box field could be added to message functions to allow pharmacists to capture this for suspected cases.

A proportion of messages were assigned to high-risk medicines, but few messages were found to relate to one of the 80 high-risk errors identified in Chapter 4 (Thomas *et al.*, 2013). This may suggest that these errors did not occur frequently or more likely that pharmacists chose to communicate directly with the physician for such problems (Liu *et al.*, 2014). It is not specifically stated in the UK standards on conduct, ethics and performance, which modality of communication pharmacists should select (General Pharmaceutical Society, 2012; p 12), rather that the *"Information is appropriately shared with other health and social care professionals involved in the care of the patient*". It is not stated in updated standards, which at the time of this study were not available for pharmacists (General Pharmaceutical Society, 2017). The appropriateness of the modality is likely to depend on the pharmacists' individual perception of the risk of an error, which will be informed by their past experiences and may therefore vary depending on their grade or length of time in practice.

6.3.1 Strengths and limitations

A strength of this study is the size of the database analysed. Over 34,000 messages and associated prescriptions were captured and a wide range of factors were coded for analysis. A proportion of the database was also independently coded, with a high inter-rater reliability demonstrated.

This study was conducted in a single-centre in England and so the results here may not reflect practice in other hospital settings that use CPOE systems, or pharmacist-physician communication in other countries. The language used by pharmacists in their written

discourse was not analysed in this study. This may change depending on the grade or prior experience of the pharmacist (Liu *et al.*, 2014) and could provide a more in-depth insight into how experience affects communication and also what is communicated. Messages were reviewed and coded to identify the explicit subject. Latent analysis is not possible without knowing the individual pharmacists and running an analysis of their intent and the subsequent interpretation of the recipient. By its very nature, coding free-text can introduce an element of subjectivity, but the inter-rater reliability study was reassuring and showed that the definitions of the codes were effective and therefore the coding consistent.

Finally, verbal communication was not investigated; a modality shown to achieve timelier acceptance of requests (Bedouch *et al.*, 2011) and may be occurring simultaneously between the pharmacist and the physician.

6.3.2 Conclusions

Pharmacists identified errors or discrepancies in the prescriptions of medicines and increasingly communicated these to the physician via the CPOE system. This occurred less frequently at weekends, indicative that medication reviews and reconciliation activities were largely conducted on the wards between a Monday and Friday. The implementation of a pharmacy service over the weekend could target the specialities found to have high numbers of messages assigned during the week, such as Medical Specialities.

Messages relating to high-risk errors were not prominent in the database, which may suggest alternative means of communication for these, or a lower rate of occurrence at the

study site. The errors and associated medicines could be used to target the optimisation of CDS to benefit patient care, with a positive impact on the workload of the pharmacist. Despite the message function being a request to review ("review message"), pharmacists still used this to provide supporting information for the physician.

Chapter 7 STATISTICAL ANALYSIS OF THE SIGN-OFF AND ACTION OF REVIEW MESSAGES

In this study, I investigate how various temporal, prescription and message factors impact on the sign-off of review messages within PICS and whether requests were actioned by the physician. I also analyse the time taken for these two tasks to be completed in practice. I demonstrate that there may be a sub-optimal use of the review message function in the clinical documentation of a message being received and potentially highlight that the function is not performing as intended in achieving a timely transfer of information to generate an effect. I describe how review messages assigned on a Friday and at the weekend take significantly longer to sign-off and action in practice, suggesting that such tasks may not be prioritised during on-call hours and that continuity of medication-related care during this time may be compromised.

The method and results presented in this chapter have been published in PLoS ONE: Pontefract, S. K., Hodson, J., Marriott, J. F., et al. (2016) Pharmacist-Physician Communications in a Highly Computerised Hospital: Sign-Off and Action of Electronic Review Messages. *PLoS ONE,* 11 (8): e0160075.

7.1 Statistical analysis

The data captured and coded in Chapter 5 were split into dichotomous and continuous outcomes.

For the dichotomous outcomes of sign-off and action, an initial univariable analysis was performed using Chi-square tests to compare the outcome rates across a range of temporal, message and prescription factors (Table 7.1–7.3)

For the continuous outcomes (time taken to sign-off and time to action), the distributions were first assessed using histograms. Neither variable was found to be normally distributed; hence parametric analyses could not be used (Figure 7.1).

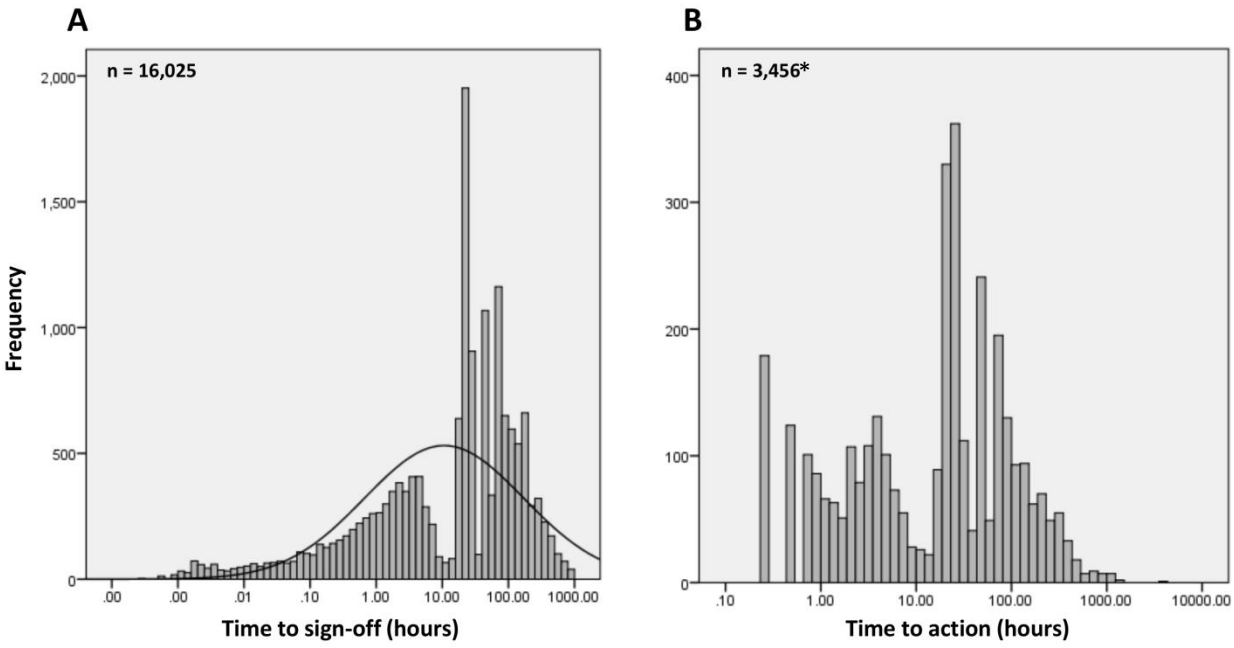


Figure 7.1 – Distribution of the times taken for review messages to be A) signed-off; and B) actioned as requested.
*Values deleted with no or negative time to action.

Owing to the skewed distributions, comparisons of these outcomes across the factors were performed using a non-parametric method, with Mann-Whitney tests used for binary factors and Kruskal-Wallis for cases with more than two categories. In addition, the continuous outcomes were dichotomised using ≤ 48 hours for time to sign-off and ≤ 24 hours for time to action and analysed using Chi-square tests.

After this initial analysis, a more comprehensive analysis of the data was performed. This was a multivariable analysis that accounted for the effects of multiple factors simultaneously and also adjusted for potential correlation between outcomes for repeated review messages on the same prescription. For example, if a physician signs off a review message on a patient's PICS profile, they are likely to sign-off other review messages that exist on the profile at the same time. Hence, review messages on the same profile could not be treated as independent. Therefore the data were analysed using multivariable Generalised Estimating Equations (GEE) (Liang & Zeger, 1986) with binary logistic models. Initially, unstructured correlation matrices were used, which allowed the model to attribute a different degree of correlation between the outcomes for each pair of messages on a prescription. This approach gave the model the greatest flexibility in attributing within-prescription correlations. However, due to the number of individual correlations in the resulting matrices, in some cases the resulting model was too complex to be produced from the available data (i.e. non-convergence), resulting in potentially unreliable results. Where this occurred, the model was repeated using an exchangeable correlation structure. This was a more straightforward approach, where the same degree of within-prescription correlation was assumed for every pair of messages. This solved the issues of non-convergence in these cases, resulting in reliable models.

Separate models were produced for the two dichotomous outcomes (sign-off and action). For the continuous outcomes (time to sign-off and time to action), the dichotomised versions described previously were used as dependent variables, as valid models could not be produced from non-Gaussian distributed data. Each model contained the temporal, message and prescription outlined and described in Table 7.1–7.3. Any categories where no outcomes occurred were excluded from the associated models, as zero counts make Odds Ratios (ORs) incalculable. In addition, correlations between the factors were assessed to identify potential multicollinearity. This found that high-risk errors were highly associated with the Route/Form theme of communication, so this factor was excluded from the analysis. For the analyses of action and time to action, the prescription status was also excluded since deleting a prescription before it could be administered was one of the behaviours being considered in the definition of an action (i.e. the outcome). The resulting models found within-prescription correlation ranging from 0.557–0.780 for the outcomes considered, supporting the decision to use the GEE methodology.

All analyses were performed using SPSS 22 (IBM SPSS Inc., Chicago, IL, USA), with $p<0.05$ considered significant. Odds ratios were plotted on a logarithmic scale to show symmetry of odds ratios of more or less than 1.

Table 7.1 – Temporal factors included in the GEE model

Temporal factor	Description	Categories
Day of the week	Day of the week the review message was assigned by the pharmacist in PICS. Saturday and Sunday grouped together owing to the low numbers assigned on these days.	Monday Tuesday Wednesday Thursday Friday Sat/Sun
Hour of day	Hour of day the review message was assigned by the pharmacist in PICS. Grouped into morning and afternoon shifts to reflect working patterns.	00:00-12:59 13:00-23:59
Time taken to assign review message	The time between the prescriptions being generated in PICS, to a review message being assigned. Numbers were assessed using histograms and categorised to allow for an even spread across the parameters.	< 12 hours 12–23:59 hours 1–6 days 7+ days

Table 7.2 – Message factors included in the GEE model

Message factor	Description	Categories
Grade of pharmacist	Grade of the pharmacist assigning the review message in PICS.	Band 6 Band 7 Band 8
Message assigned to a high-risk medicine	High-risk medicines were identified	No Yes
Message assigned to a high-risk error	High-risk errors were identified	No Yes
Message related to medicines reconciliation	Communications were identified that related to a disparity between the patient's current prescription and the patients medicines on admission.	No Yes
Message associated with the prescription	Messages were reviewed and identified as to whether they were associated with the prescription on which they were assigned.	No Yes
Communication theme	Theme of communication in the review message. Themes developed and defined by consensus.	Dose/Frequency Contraindication Drug Form/Route Drug Interaction Drug Selection Drug Use/ Administration Logistics Omission Other Supporting Information
Profession of person signing off the review message	The profession of the user signing off the review message.	Pharmacist Consultant Junior SPR/NMP*

*NMP Non-medical prescriber; SPR Specialist registrar. NMPs were grouped with SPRs owing to small numbers (n=86).

Table 7.3 – Prescription factors included in the GEE model

Prescription factor	Description	Factor
Speciality	The speciality the patient was under the care of when the review message was assigned. Medical Admissions were separated from General Medicine owing to the difference in pharmacist presence in this setting. Medical specialities: *Renal; Liver; Neurology; Cardiology; Haematology; Oncology; Ambulatory Care*. Surgical specialities: *Ear, nose and throat; Cardiothoracic; Maxillofacial; Plastics; Urology; Vascular*	Medical Admissions Critical Care and Burns General Medicine General Surgery Medical Specialities Surgical Specialities TNO
BNF Group	The prescription medicine was categorised according to the chapters of the British National Formulary. These were further categorised into a second level categorisation to facilitate descriptive analysis.	Cardiovascular Central nervous system Endocrine Eye, Ear, nose and oropharynx Gastrointestinal Infection Malignant disease and immunosuppression Musculoskeletal and joint disease Nutrition and blood Obstetrics, gynaecology and urinary-tract disorders Other Respiratory Skin
Regularity of prescription	The regularity of the prescriptions were further categorised Regular; *Regular; Continuous infusion;* Once only dose; When required: *When required; When required infusion;* TTO: *Regular at home; When required at home; and Once only at home).*	Regular As Required Once-Only TTO
Prescription status	D: *Deleted* (the prescription was deleted before any doses were administered). C: *Continued* (the prescription was administered).	Continued Deleted

7.2 Results

Of the 34,506 review messages analysed, 46.6% (n=16,025/34,506) were signed-off in PICS, the majority of which were by junior physicians (39.5%, n=6,329/16,025) and pharmacists (39.3%, n=6,302/16,025) (Figure 7.2).

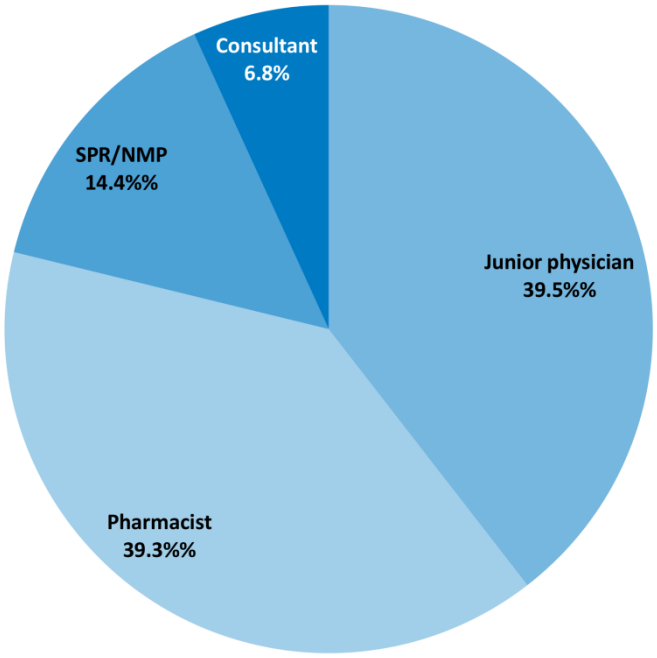


Figure 7.2 – Pie chart to show the frequency of sign-off by profession

Most messages were signed-off between a Monday and Friday (98.8%, n=15,854/16,025). Of those that were signed-off at the weekend, a higher proportion were signed-off on a Saturday (63.7%, n=109/171) compared to a Sunday (36.3%, n=62/171). The proportions of messages signed-off by the various professions remained consistent throughout the week (Figure 7.3).

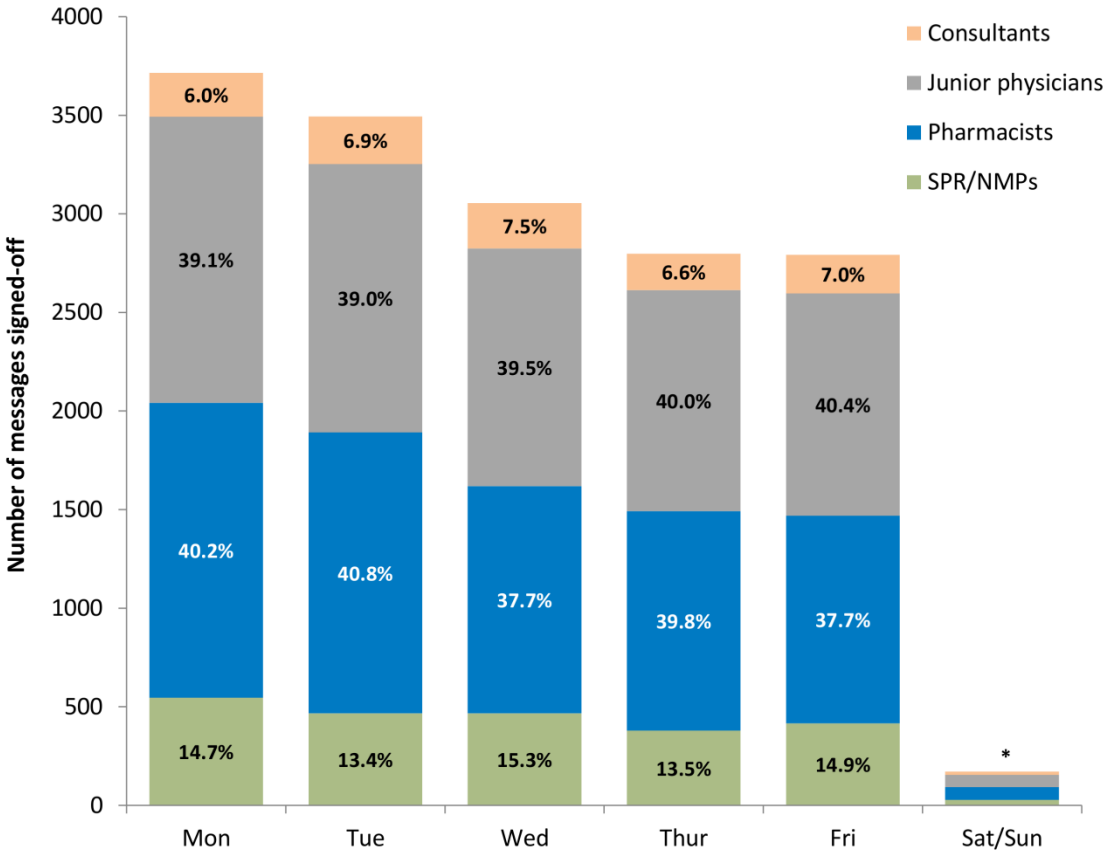


Figure 7.3 – Sign-off of messages by profession and by day of week
*9.9% Consultants; 36.2% Junior physicians; 37.4% Pharmacists; 16.4% SPR/NMPs

The majority of messages were signed-off between 08:00–18:00 (95.1%, 15,244/ 16,025), with peaks in the rate observed between 10:00–11:00 and again at 15:00–16:00 by all professions (Figure 7.4). Of those that were signed-off, 65.5% (n=10,502/16,025) were completed within 48 hours.

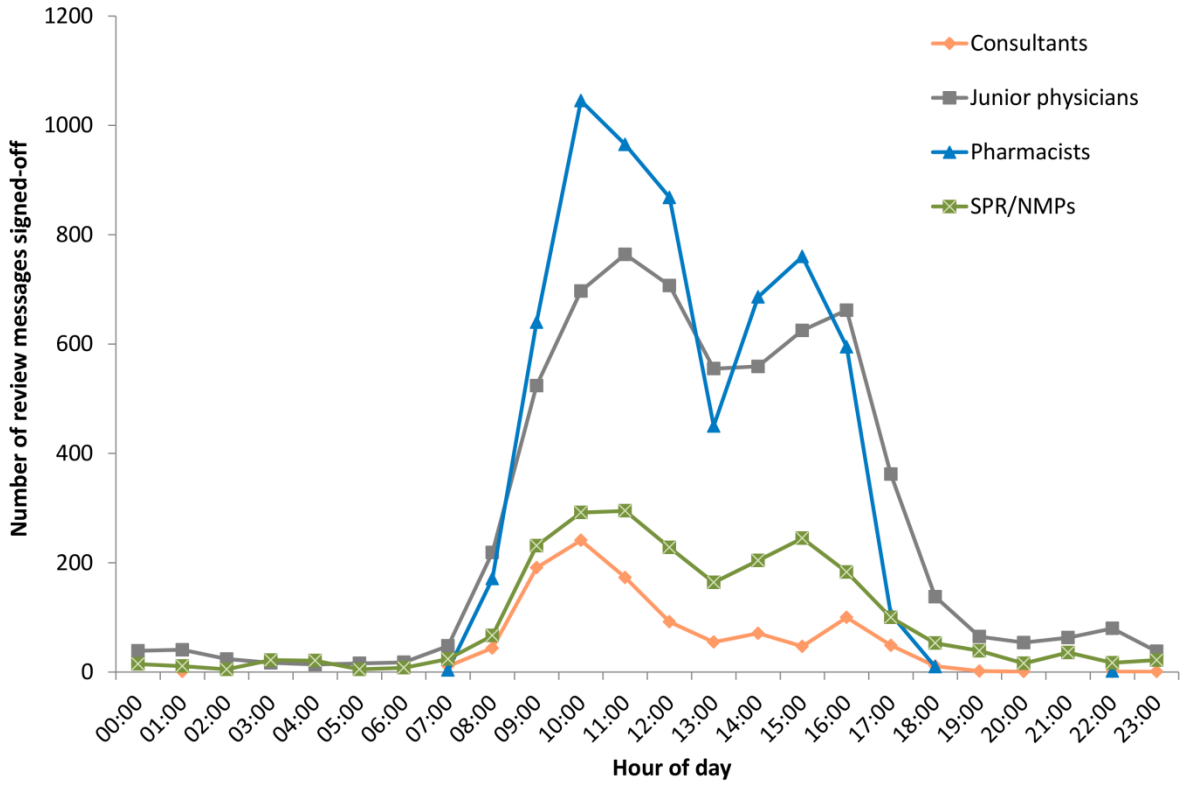


Figure 7.4 – Sign-off of messages by professions by hour of day

After accounting for those messages that were not directly associated with the prescription or where an action could not be determined, 9,991 were identified for further analysis to determine if they led to an action (Figure 7.2). Of these, just over a third of the prescriptions were amended in-line with the pharmacists' requests (35.8%, n=3,575/9,991) and 57.0% (n=2,036/3,575) were actioned within 24 hours.

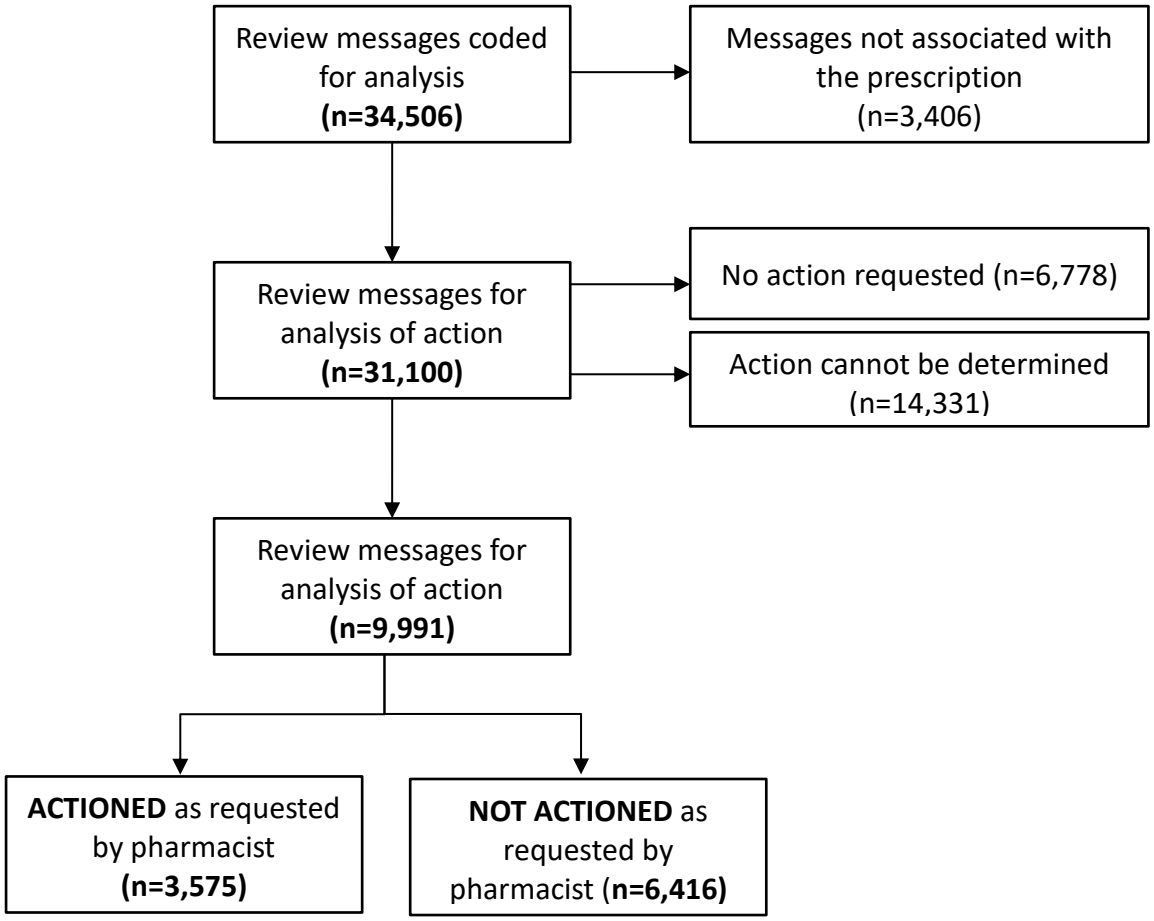


Figure 7.5 – Flow chart to show the process of identifying messages that could be assessed for action or no action

Where messages were actioned, the majority of the modifications to the prescriptions were made between a Monday and Friday (94.1%, n=3,364/3,575). With exception of a Monday, a slightly higher proportion of messages were actioned in the morning shift between 00:00–12:59, compared to the afternoon between 13:00–23:59 (Figure 7.6). Peaks were observed in the action of messages at 11:00 and 16:00 (Figure 7.7), similar to those observed for sign-off.

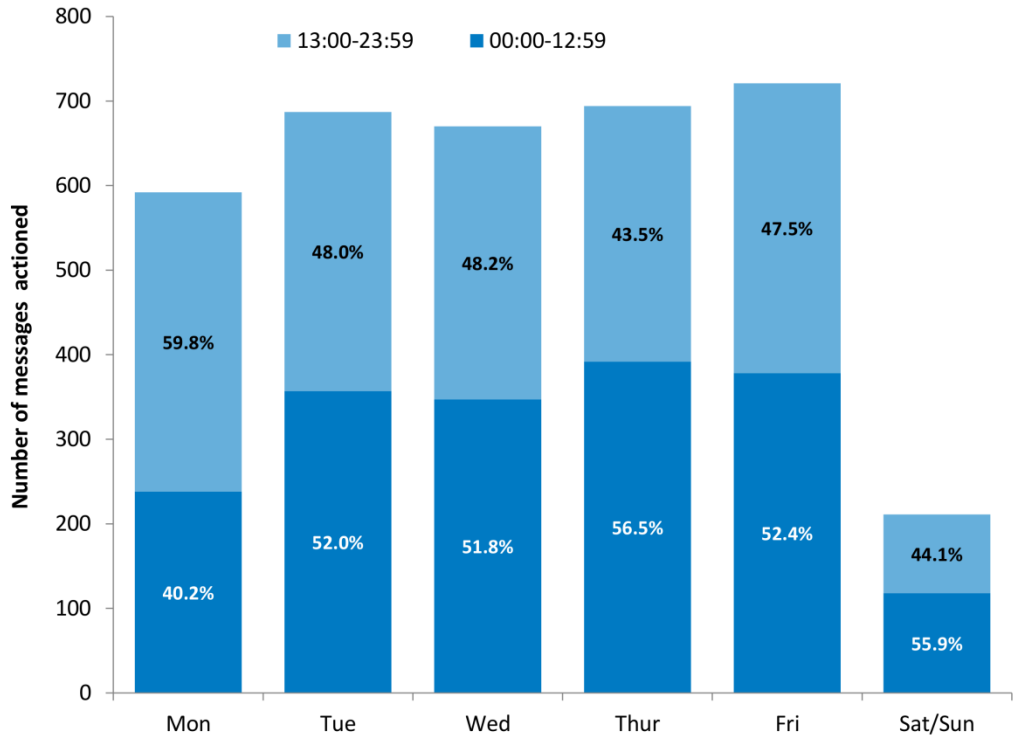


Figure 7.6 – Action of requests by day of week and shift

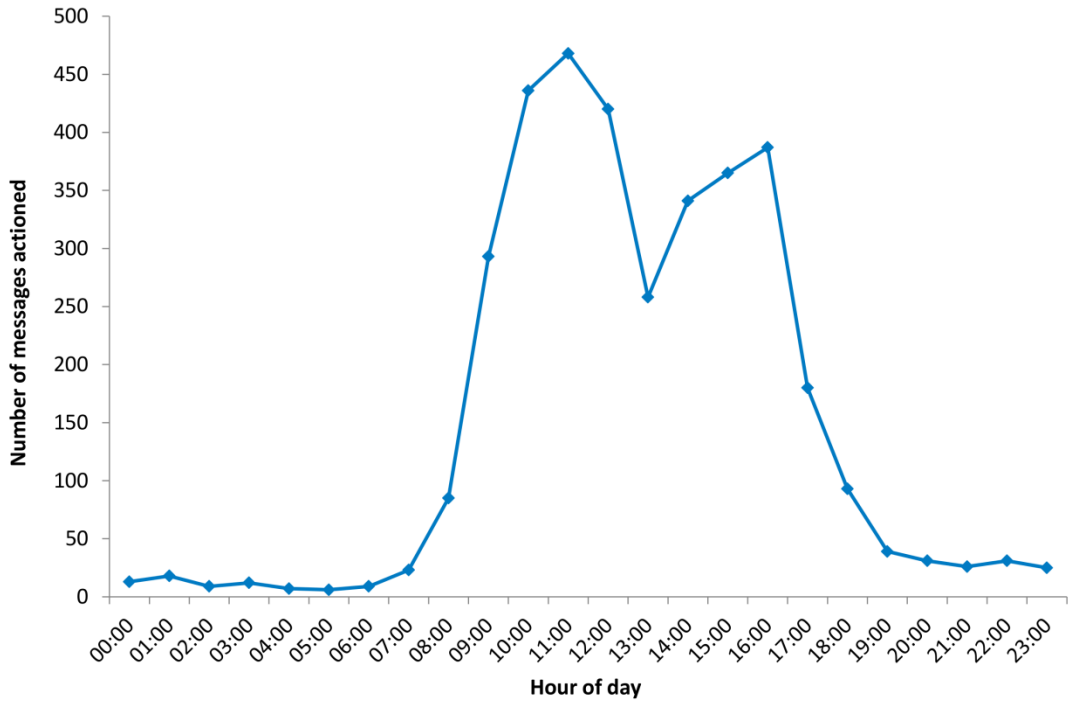


Figure 7.7 Figure – Action of requests by hour of day

The results of this statistical analysis will be approached to consider each of the temporal, message and prescription factors in turn for each of the four outcomes: 1) sign-off of review messages; 2) time to sign-off in ≤ 48 hours; 3) action of requests; and, 4) time to action requests in ≤ 24 hours. The GEE model described accounts for all factors in Table 7.1−7.3 simultaneously.

7.2.1 Temporal factors

The results tables of the GEE analysis for temporal factors can be found in tables 7.4 and 7.5 and Appendices 9–12.

7.2.1.1 Day of the week review message assigned

The rate of sign-off was significantly different across the days of the week (p=0.002), with messages less likely to be signed-off at the weekend (p=0.001, OR 0.706, 95% CI 0.570–0.875) compared to a Monday (Figure 7.8[A]). Where messages were signed off, this was significantly less likely to occur in ≤ 48 hours if they were assigned on a Friday (p<0.001, OR 0.439, 95% CI 0.392–0.491) or at the weekend (p<0.001, OR 0.381, 95% CI 0.268–0.542) with median times to sign-off 42.5 hours (range: 1.6–96.5) and 47.1 hours (4.7–72.6) respectively, compared to 23.3 hours (2.4–69.4) on a Monday. Messages assigned on a Thursday were signed off quicker than any other day of the week (p=0.008, OR 0.856, 95% CI 0.763–0.961) with a median time of 22.6 hours (2.0–96.1).

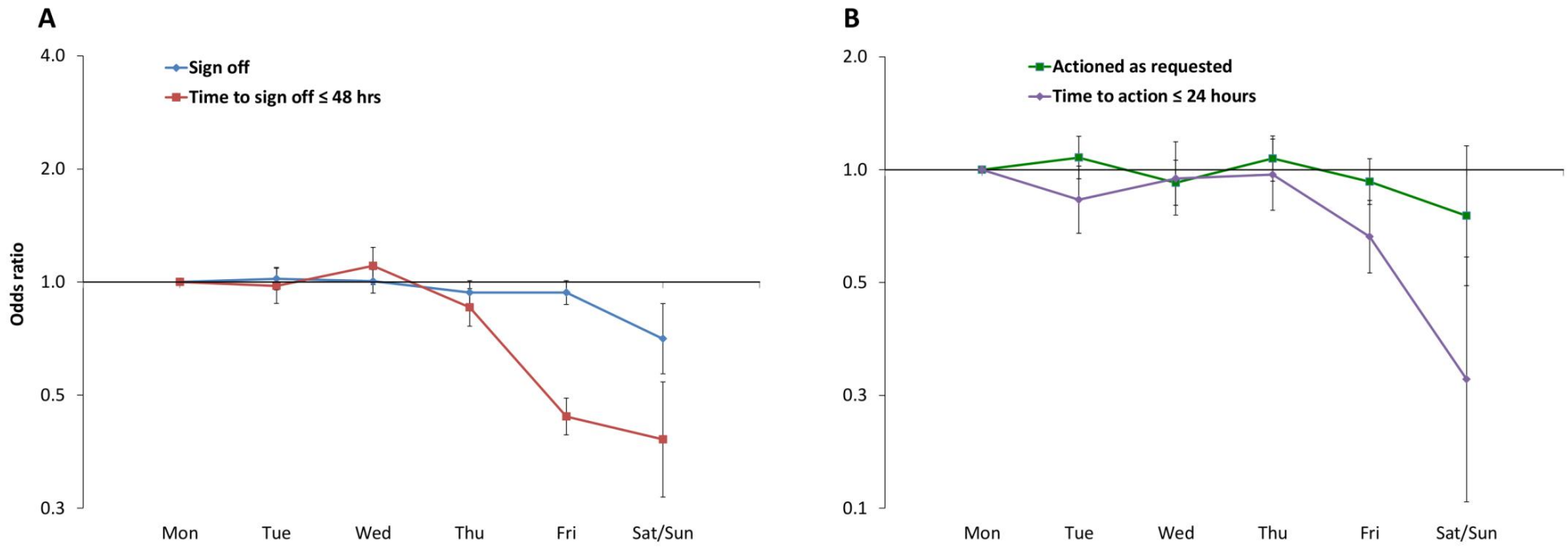


Figure 7.8 – GEE model for day of the week

A: Sign-off and time taken to sign-off in ≤48 hours; B: Action and time to action as requested in ≤ 24 hours. ORs (95% CI) from the GEE model described in Appendices 9–12. Monday is the reference category and the y-axis uses a logarithmic scale

The rate at which messages were actioned did not change significantly across the days of the week (p=0.073, Figure 7.8[B]). Where messages were actioned, this was less likely to occur in ≤ 24 hours if they were assigned on a Friday (p<0.001, OR 0.663, 95% CI 0.530–0.828) or at the weekend (p=0.001, OR 0.276, 95% CI 0.130–0.585) relative to a Monday. The median time to action was 22.8 hours (range 1.9–94.1) and 37.3 (10.1–54.1) hours respectively, compared to 20.2 (2.2–48.2) hours on Monday.

7.2.1.2 Hour of day review message is assigned

The hour of day the pharmacist assigned the review messages did not have a significant impact on the rate of sign-off (p=0.086). However those assigned in the afternoon (13:00–23:59) were less likely to be signed-off in ≤ 48 hours (p=0.013, OR 0.911, 95% CI 0.846–0.981), with a median time of 23.5 hours (95% CI 2.6–89.5) compared to 23.3 hours (2.1–72.8) in the morning. No significant difference was detected in the rate of action (p=0.847) or time to action (p=0.714) by time of day.

7.2.1.3 Time between prescription being generated and message being assigned

The time between the prescription being generated and the review message being assigned had a significant impact on the rate of sign-off (p<0.001). Where messages were signed-off, this was significantly less likely to occur in ≤ 48 hours if they were assigned to prescriptions generated 7 or more days ago, compared to within the last 12 hours (p=0.001, OR 0.424, 95% CI 0.365–0.492). The former group took on average over twice as long to be signed-off, with a median time of 50.8 hours (range: 12.6–166.6) compared to 20.0 hours (1.2–48.2)

(Figure 7.9[A]). Messages assigned within 1–6 days were more likely to be signed off ($p<0.001$, OR 0.892, 95% CI 0.837–0.949) compared to those assigned in < 12 hours.

A similar pattern was observed for those that were actioned, with messages assigned to prescriptions that were generated 7 or more days ago significantly less likely to be actioned in ≤24 hours ($p<0.001$, OR 0.559, 95% CI 0.402–0.777), taking almost twice as long than those assigned within 12 hours (median 40.3 Vs. 21.6 hours, Figure 7.9[B]).

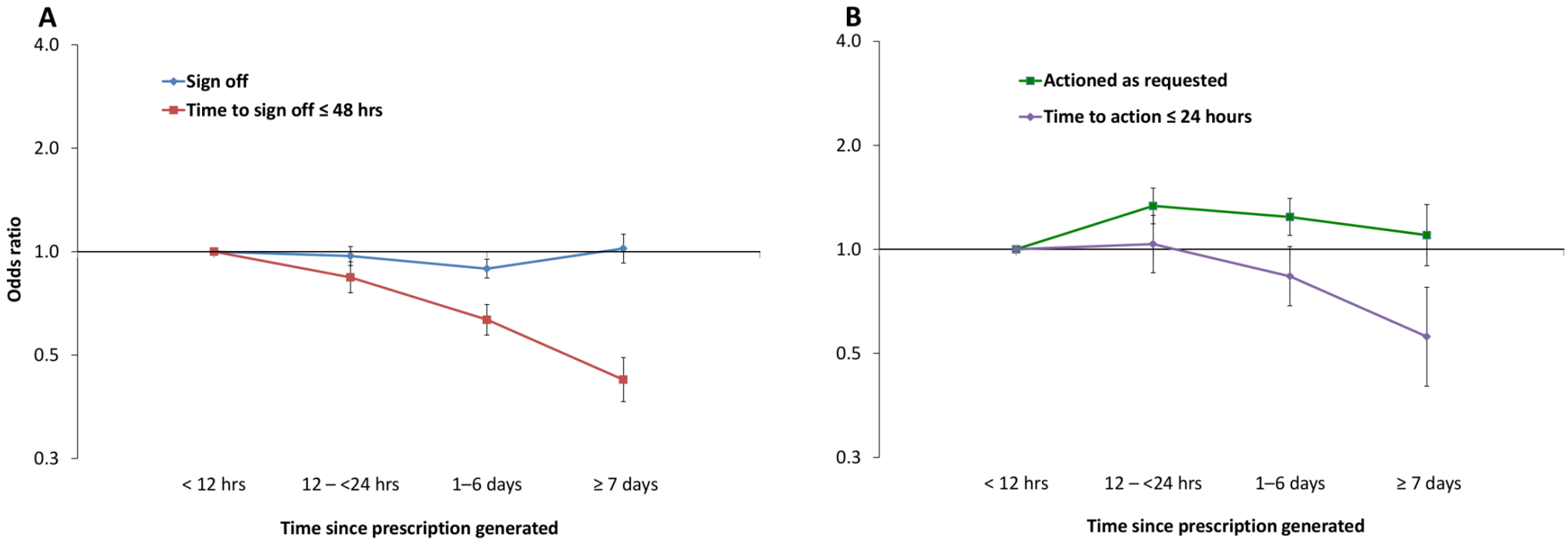


Figure 7.9 – GEE model for the time since the prescription was generated to the message being assigned.
A: Sign-off and time to sign-off in ≤ 48 hours; B: Action and time to action as requested in ≤ 24 hours. ORs (95% CI) from the GEE model described in Appendices 9–12. < 12 hours is the reference category

Table 7.4 – GEE results for temporal factors for sign-off rates and time to sign-off in ≤48 hours

	GEE of Sign-off Rates		GEE of Time to Sign-off ≤ 48 hours		% of Messages Signed-off	Hours to Sign-off (Median, Range)
	Odds Ratio (95% CI)	*p-value*	*Odds Ratio (CI)*	*p-value*		
Day of the week review message assigned		**0.002***		**<0.001***		
Monday	1	–	1	–	47.0%	23.2 (2.4–69.4)
Tuesday	1.020 (0.953–1.093)	0.563	0.977 (0.877–1.088)	0.670	47.4%	23.3 (2.7–65.7)
Wednesday	1.004 (0.935–1.079)	0.903	1.104 (0.984–1.237)	0.091	47.4%	23.1 (2.2–52.7)
Thursday	0.937 (0.871–1.008)	0.081	0.856 (0.763–0.961)	0.008*	45.3%	22.6 (2.0–96.1)
Friday	0.937 (0.872–1.008)	0.082	0.439 (0.392–0.491)	<0.001*	45.4%	42.5 (1.6–96.5)
Sat/Sun	0.706 (0.570–0.875)	0.001*	0.381 (0.268–0.542)	<0.001*	36.6%	47.1 (4.7–72.6)
Hour of day review message assigned		**0.086**		**0.013***		
00:00–12:59	1	–	1	–	46.7%	23.3 (2.1–72.8)
13:00–23:59	1.043 (0.994–1.093)	0.086	0.911 (0.846–0.981)	0.013*	46.1%	23.5 (2.6–89.5)
Time from prescription generated to message assigned		**<0.001***		**<0.001***		
< 12 hours	1	–	1	–	45.6%	20.0 (1.2–48.2)
12–23:59 hours	0.971 (0.911–1.035)	0.367	0.841 (0.758–0.934)	0.001*	47.6%	22.4 (2.0–70.8)
1–6 days	0.892 (0.837–0.949)	<0.001*	0.633 (0.572–0.701)	<0.001*	46.0%	25.5 (3.1–92.9)
7+ days	1.020 (0.926–1.124)	0.682	0.424 (0.365–0.492)	0.001*	47.2%	50.8 (12.6–166.6)

*Significant at p<0.05

Results from GEEs accounting for all factors in tables 7.1–7.2, with the exception of Message factors 'Messages assigned to high-risk error' and 'Messages associated with prescription', which were excluded from the analysis owing to multicollinearity. SIGN-OFF: Profession of person signing off the message was excluded from the analysis since the profession of unsigned messages is not possible to determine.

Table 7.5 – GEE results for temporal factors for action rates and time taken to action in ≤24 hours

	GEE of Action Rates		GEE of Time to Action ≤ 24 hours		% of Messages Actioned	Hours to Action (Median, Range)
	Odds Ratio (95% CI)	*p-value*	*Odds Ratio (CI)*	*p-value*		
Day of the week review message assigned		**0.073**		**<0.001***		
Monday	1	–	1	–	35.7%	20.2 (2.2–48.2)
Tuesday	1.078 (0.945–1.229)	0.263	0.831 (0.676-1.022)	0.079	37.8%	22.1 (2.4–47.3)
Wednesday	0.923 (0.804–1.060)	0.256	0.948 (0.757-1.187)	0.640	34.6%	22.3 (2.4–48.0)
Thursday	1.071 (0.932–1.231)	0.332	0.970 (0.779-1.208)	0.785	36.9%	21.4 (2.3–45.4)
Friday	0.930 (0.808–1.070)	0.309	0.663 (0.530-0.828)	<0.001*	34.2%	22.8 (1.9–94.1)
Sat/Sun	0.754 (0.490–1.158)	0.197	0.276 (0.130-0.585)	0.001*	27.1%	37.3 (10.1–54.1)
Hour of day review message assigned		**0.847**		**0.714**		
00:00–12:59	1	–	1	–	36.7%	21.6 (2.2–49.2)
13:00–23:59	0.991 (0.903–1.087)	0.847	0.973 (0.840-1.127)	0.714	34.3%	22.1 (3.1–69.1)
Time from prescription generated to message assigned		**<0.001***		**0.001***		
< 12 hours	1	–	1	–	31.2%	21.6 (3.1–44.2)
12–23:59 hours	1.335 (1.186–1.503)	<0.001*	1.036 (0.856-1.254)	0.719	39.5%	19.0 (1.9–45.6)
1–6 days	1.241 (1.097–1.404)	0.001*	0.836 (0.686-1.019)	0.076	36.8%	22.7 (2.2–69.8)
7+ days	1.099 (0.896–1.347)	0.364	0.559 (0.402-0.777)	0.001*	32.7%	40.3 (3.4–139.4)

*Significant at p<0.05. Results from GEEs accounting for all factors in tables 7.1–7.2, with the exception of Prescription Factor 'Prescription status' which was excluded from the analysis of action and time to action as this can be considered an outcome. ACTION: Categories with zero counts (BNF category 'Other' and Regularity 'As required' and 'Once-only') were excluded from the analysis. TIME TO ACTION: Categories with zero counts (Communication theme: 'Contraindication', 'Drug Interaction'; 'Drug Selection'; 'Omission' 'Other' and 'Supporting Information' were excluded from the analysis.

7.2.2 Message factors

The results tables of the GEE analysis for message factors can be found in tables 7.6 and 7.7 and Appendices 9–12. Messages associated with high-risk error were excluded owing to multicollinearity.

7.2.2.1 Grade of pharmacist

The sign-off rate was significantly different across the grades of the pharmacist (p=0.010), with messages assigned by grade 8 pharmacists least likely to be signed-off (p=0.004, OR 0.899, 95% CI 0.835–0.967) compared to grade 6. There was no significant difference found for grade 7 (p=0.506, OR 0.980, 95% CI 0.925–1.039). Where messages were signed-off, there was no significant difference across the grades for the time taken in $\leq$ 48 hours (p=0.368), with the median time to sign-off ranging from 22.4–25.5 (2.1–94.3) hours.

The rate of action was also found to be significant across the grades (p=<0.001). In contrast to sign-off, messages from the grade 8 pharmacists were the most likely to be actioned (p<0.001, 1.379 95% CI: 1.182–1.607 Vs. grade 6), whilst messages from grade 7 pharmacists that were actioned were most likely to be actioned in ≤24 hours (p<0.001, OR 1.408, 95% CI: 1.167–1.698).

Where messages were actioned, this was more likely to occur in $\leq$24 hours if they with assigned by grade 7 pharmacists (p<0.001, OR 1.408 (1.167–1.698), with a median time of 20.4 hours (2.2–47.5) compared to 25.2 hours (3.8-78.1) for grade 6.

7.2.2.2 High-risk medicine

Messages assigned to high-risk medicines were significantly less likely to be signed-off ($p<0.001$, OR 0.841, 95% CI 0.789–0.895) or actioned ($p=0.012$, OR 0.848, 95% CI 0.745–0.964) than those assigned to other medicines. No significant association was detected between high-risk medicines and the time taken to sign-off or action ($p=0.713$ and $p=0.707$ respectively). The median time taken to action messages assigned to high-risk medicines was 20.2 hours (1.9–47.8) compared to 22.1 hours (2.4–57.1) for those that were not coded as high-risk.

7.2.2.3 Medicines reconciliation

Messages communicating information relating to a disparity between the current inpatient prescription and the patient's pre-admission medicines were more likely to be signed-off in PICS ($p<0.004$, OR 1.082 (1.025–1.142) compared to those that did not. Where messages were signed-off, this was also significantly more likely to occur in $\leq$48 hours ($p<0.001$, OR 1.210, 95% CI 1.110–1.319), with a median time of 22.4 hours (1.9–70.2), compared to 21.8 hours (1.9–66.8). Messages were more likely to be actioned if they were related to medicines reconciliation ($p<0.001$, OR 1.278, 95% CI 1.144–1.428), however the rate of action in ≤24 hours was not found to change significantly, with a median of 23.1 hours (2.3–67.9), compared to 24.7 hours (3.4-75.5) for messages unrelated to the reconciliation process.

7.2.2.4 Communication theme

The theme of communication had a significant impact on whether messages were signed-off ($p<0.001$). With the exception of communications categorised as Other, all communications

were significantly less likely to be signed-off compared to Dose/Frequency, with those related to Contraindication the least likely to be signed-off. Messages relating to a Contraindication were also least likely to be signed-off ≤48 hours (p=0.004, OR 0.721, 95% CI 0.579–0.899 Vs. Dose/Frequency). The rate of action was also found to differ significantly across the categories (p=0.014), with those relating to 'Drug Use/Administration' least likely to be actioned (p=0.035, OR 0.680, 95% CI 0.475–0.973) Vs. Dose/Frequency). There was no significant difference in the time taken to action across the themes (p=0.581).

7.2.2.4 Profession of signed user

The profession of the signed user was considered in the GEE for time to sign-off. Compared to pharmacists, messages were more likely to be signed-off by consultants (p=0.028, OR 1.203, 95% CI 1.020–1.420) and junior physicians (P=0.001, OR 1.159, 95% CI 1.061–1.267), with a median time to sign-off of 22.2 hours (3.1–67.9) and 22.9 hours (2.7–70.9) respectively.

Table 7.6 – GEE results for message factors for sign-off rates and time to sign-off in ≤48 hours

	GEE of Sign-off Rates		GEE of Time to Sign-off ≤ 48 hours		% of Messages Signed-off	Hours to Sign-off (Median, Range)
	Odds Ratio (95% CI)	*p-value*	*Odds Ratio (CI)*	*p-value*		
Grade of the pharmacist		**0.010***		**0.368**		
6	1	–	1	–	46.4%	25.5 (2.1–94.3)
7	0.980 (0.925–1.039)	0.506	1.065 (0.972–1.167)	0.178	46.7%	22.4 (2.1–71.3)
8	0.899 (0.835–0.967)	0.004*	1.068 (0.943–1.209)	0.300	45.9%	23.4 (2.4–71.8)
Message assigned to a high-risk medicine		**<0.001***		**0.713**		
No	1	–	1	–	47.8%	23.1 (2.1–73.4)
Yes	0.841 (0.789–0.895)	<0.001*	0.982 (0.890–1.083)	0.713	43.0%	24.1 (2.7–75.4)
Message relates to medicines reconciliation		**0.004***		**<0.001***		
No	1	–	1	–	43.1%	23.3 (2.2–73.5)
Yes	1.082 (1.025–1.142)	0.004*	1.210 (1.110–1.319)	<0.001*	50.7%	25.1 (2.9–96.5)
Communication theme		**<0.001***		**<0.001***		
Dose/Frequency	1		1	–	54.2%	23.2 (2.4–71.7)
Contraindication	0.498 (0.439–0.566)	<0.001*	0.721 (0.579–0.899)	0.004*	33.5%	40.7 (2.9–120.0)
Drug Form/Route	0.640 (0.581–0.705)	<0.001*	1.139 (0.969–1.339)	0.116	44.0%	22.6 (1.7–71.9)
Drug Interaction	0.733 (0.633–0.850)	<0.001*	0.989 (0.777–1.261)	0.932	46.6%	27.0 (2.9–120.2)
Drug Selection	0.537 (0.494–0.584)	<0.001*	1.119 (0.969–1.291)	0.126	35.6%	23.2 (2.2–72.1)
Drug Use/Admin	0.604 (0.562–0.649)	<0.001*	0.863 (0.764–0.974)	0.017*	39.4%	23.6 (1.7–72.3)
Logistics	0.560 (0.471–0.665)	<0.001*	0.957 (0.717–1.278)	0.767	37.1%	27.0 (3.7–89.7)
Omission	0.820 (0.764–0.880)	<0.001*	0.043 (0.938–1.159)	0.437	50.1%	21.7 (2.0–66.8)
Other	0.864 (0.733–1.018)	0.080	0.566 (0.418–0.766)	<0.001*	39.2%	24.9 (2.7–117.9)
Supporting Info	0.801 (0.755–0.850)	<0.001*	0.956 (0.872–1.048)	0.339	48.4%	23.8 (2.1–92.9)
Profession		–		**0.001***		
Pharmacist	–	–	1	–	–	23.7 (0.7–91.7)
Consultant	–	–	1.203 (1.020–1.420)	0.028*	–	22.2 (3.1–67.9)
Junior	–	–	1.159 (1.061–1.267)	0.001*	–	22.9 (2.7–70.9)
SPR/NMP	–	–	0.976 (0.867–1.099)	0.690	–	24.3 (4.2–78.2)

*Significant at p<0.05. Results from GEEs accounting for all factors in tables 7.1–7.2, with the exception of Message factors 'Messages assigned to high-risk error' and 'Messages associated with prescription', which were excluded from the analysis owing to multicollinearity. SIGN-OFF: Profession of person signing off the message was excluded from the analysis since there is no profession for messages that were not signed-off.

Table 7.7 – GEE results for message factors for action rates and time taken to action in ≤24 hours

	GEE of Action Rates		GEE of Time to Action ≤ 24 hours		% of Messages Actioned	Hours to Action (Median, Range)
	Odds Ratio (95% CI)	*p-value*	*Odds Ratio (CI)*	*p-value*		
Grade of the pharmacist		**<0.001***		**0.002***		
6	1	–	1	–	31.9%	25.2 (3.8–78.1)
7	1.203 (1.061–1.365)	0.004*	1.408 (1.167-1.698)	<0.001*	38.1%	20.4 (2.2–47.5)
8	1.379 (1.182–1.607)	<0.001*	1.293 (1.013-1.651)	0.039*	35.1%	20.2 (1.7–51.4)
Message assigned to a high-risk medicine		**<0.001***		**0.707**		
No	1	–	1	–	36.4%	22.1 (2.4–57.1)
Yes	0.848 (0.745–0.964)	<0.001*	1.040 (0.846-1.279)	0.707	33.9%	20.4 (1.9–48.2)
Message relates to medicines reconciliation		**0.004***		**0.859**		
No	1	–	1	–	30.3%	24.7 (3.4-75.5)
Yes	1.278 (1.144–1.428)	0.004*	1.016 (0.852-1.212)	0.859	42.5%	23.1 (3.2-68.3)
Communication theme		**<0.001***		**0.581**		
Dose/Frequency	1		1	–	36.4%	21.6 (2.4–51.6)
Drug Form/Route	1.099 (0.941–1.285)	<0.001*	0.992 (0.775-1.268)	0.992	33.9%	22.8 (1.4–72.0)
Drug Use/Admin	0.680 (0.475–0.973)	<0.001*	0.946 (0.551-1.623)	0.839	25.2%	24.2 (3.5–52.7)
Logistics	1.936 (0.985–3.807)	<0.001*	0.453 (0.148-1.386)	0.165	24.5%	51.4 (22.6–96.5)

**Significant at p<0.05. Results from GEEs accounting for all factors in tables 7.1–7.2, with the exception of Message factors 'Messages assigned to high-risk error' and 'Messages associated with prescription', which were excluded from the analysis of action and time to action owing to multicollinearity.*
Prescription Factor: 'Prescription status' was excluded from the analysis of action and time to action as this can be considered an outcome.
ACTION: Categories with zero counts (BNF category 'Other' and Mode 'As required' and 'Once-only') were excluded from the analysis.
TIME TO ACTION: Categories with zero counts (Communication theme: 'Contraindication', 'Drug Interaction'; 'Drug Selection'; 'Omission' 'Other' and 'Supporting Information' were excluded from the analysis.

7.2.3 Prescription factors

The results tables of the GEE analysis for prescription factors can be 7.8 and 7.9 and Appendices 9–12.

7.2.3.1 Speciality

The rate of sign-off ($p<0.001$) and time taken to sign-off ($p<0.001$) were found to differ significantly across the specialties (Figure 7.10[A]). Where messages were signed-off, this was significantly less likely to occur in ≤48 hours if they were assigned to patients in Trauma and Orthopaedics (TNO) than those in Medical Admissions, taking on average over twice as long ($p<0.001$, OR 0.419, 95% CI 0.349–0.502)—median: 51.3 hours versus 20.5 hours. There was a significant difference in the rate of messages being actioned ($p<0.001$) across the specialities (Figure 7.10[B]). Messages were least likely to be actioned in ≤24 hours if they were assigned to prescriptions for patients in TNO compared to Medical Admissions ($p=0.004$, OR 0.598, 95% CI 0.422–0.848), with median times of 28.3 hours (range: 7.2–110.9) compared to 19.9 hours (2.2–36.0).

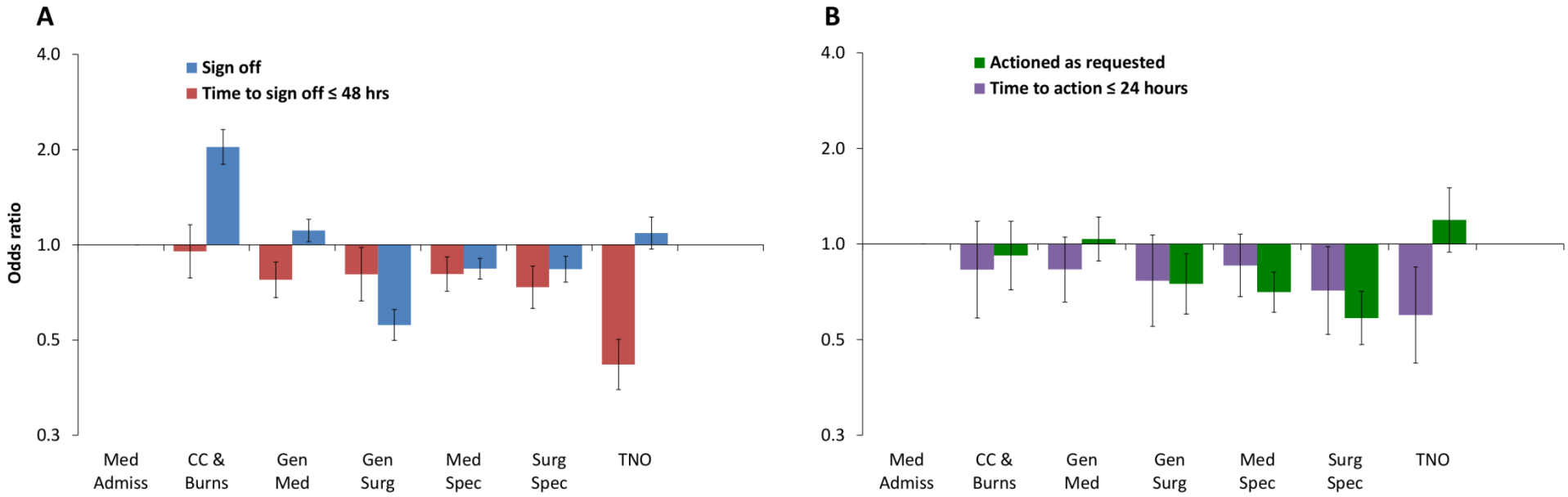


Figure 7.10– GEE model for speciality. A: Sign-off and time taken to sign-off in ≤48 hours; B: Action and time to action as requested in ≤ 24 hours

ORs (95% CI) from the GEE model described in Appendices 9-12. Medical Admissions is the reference category. CC: Critical Care; Med: Medicine; Surg: Surgery; Spec: Specialities; TNO: Trauma and Orthopaedics

7.2.3.2 Category of medicine

The rate of sign-off of messages was found to be significant across the categories of medicine ($p<0.001$), with those assigned to Cardiovascular medicines more likely to be signed-off compared to all other categories of medicine. Where messages were signed-off, the time taken ≤48 hours was also found to be significant ($p<0.001$). Anti-infective medicines (Infection category) stood out amongst all the categories, being twice as likely to be signed-off in ≤48 hours ($p<0.001$, OR 2.062, 95% CI 1.775–0.563) compared to Cardiovascular medicines, with a median time to sign-off of 19.9 hours (1.3–47.7) compared to 24.8 hours (3.0–95.7).

The rate of action and time to action was also significant across the categories ($p <0.001$, $p=0.001$), with anti-infectives most likely to be actioned ($p=0.013$, OR 1.246, 95% CI 1.048–1.482) compared to Cardiovascular, followed by those assigned to Central Nervous System medicines ($p=0.020$, OR 1.162, 95% CI 1.024–1.320). Messages assigned to anti-infectives were actioned nearly four times faster than messages assigned to Cardiovascular medicines ($p<0.001$, OR 2.055, 95% CI 1.546–2.732), with a median time to action of 6.0 hours (1.2–26.4) compared to 23.0 hours (3.4–68.8).

7.2.3.3 Regularity of prescription

The regularity (or mode) of the prescription had a significant impact on the rate of sign-off ($p<0.001$), with all modes less likely to be signed-off compared to messages on Regular prescriptions. However, where messages were signed-off, this was found to occur significantly quicker for those assigned to Once-only ($p=0.001$, OR 11.077, 95% CI 2.581–47.533) and TTO prescriptions ($p<0.001$, OR 2.818, 95% CI 2.321–3.421)—with a respective

median time to sign-off of 1.8 hours (0.1–20.2) and 2.1 hours (0.3–26.2), compared to 23.7 hours (2.5–73.8) for Regular medicines. As required prescriptions took significantly longer (p=0.004, OR 0.813, 95% CI 0.780–0.935), with a median time of 30.9 hours (3.7–119.9).

Since messages on Once-only and TTO prescriptions were less frequent and rarely specified actions, prescriptions of these types were excluded from the analysis of action. The analysis found that the messages assigned to 'As required' prescriptions were significantly less likely to be actioned than those on Regular prescriptions (p<0.001, OR 0.374, 95% CI 0.317–0.442). There was no significant difference in the time taken to action in ≤24 hours (p=0.468).

7.2.3.4 Prescription status

Messages assigned to Deleted prescriptions were significantly less likely to be signed-off than those for Completed prescriptions (p=0.005, OR 0.898, 95% CI 0.832–0.968). However, a higher proportion were signed-off in ≤48 hours (p<0.001, OR 1.739, 95% CI 1.520–1.989)—median time of 5.3 hours (0.8-44.1) compared to 24.0 hours (2.5–76.2) for prescriptions that were continued. Prescription status was not included in the analyses of action and time to action, since a deleted prescription was considered an outcome.

Table 7.8 – GEE results for prescription factors for sign-off rates and time to sign-off in ≤48 hours

	GEE of Sign-off Rates		GEE of Time to Sign-off ≤ 48 hours		% Messages Signed-off	Hours to Sign-off (Median, Range)
	Odds Ratio (95% CI)	*p-value*	*Odds Ratio (CI)*	*p-value*		
Speciality		**<0.001***		**<0.001***		
Medical Admissions	1	–	1	–	52.5%	20.5 (1.7–48.2)
Critical Care and Burns	2.038 (1.796–2.314)	<0.001*	0.954 (0.786–1.157)	0.630	63.0%	23.9 (3.0–72.4)
General Medicine	1.111 (1.024–1.205)	0.011*	0.775 (0.681–0.883)	<0.001*	49.2%	24.9 (2.4–94.5)
General Surgery	0.558 (0.498–0.625)	<0.001*	0.807 (0.664–0.981)	0.031*	33.3%	23.0 (1.4–76.6)
Medical Specialities	0.840 (0.780–0.906)	<0.001*	0.809 (0.714–0.917)	0.001*	41.5%	23.2 (2.2–72.4)
Surgical Specialities	0.837 (0.763–0.919)	<0.001*	0.735 (0.630–0.857)	<0.001*	41.9%	23.9 (2.5–76.9)
TNO	1.090 (0.970–1.226)	0.147	0.419 (0.349–0.502)	<0.001*	47.0%	51.3 (19.3–167.5)
BNF category		**<0.001***		**<0.001***		
CVS	1		1		51.3%	24.8 (3.0–95.7)
CNS	0.955 (0.891–1.023)	0.189	1.256 (1.131–0.884)	<0.001*	44.4%	23.7 (2.3–78.1)
Endocrine	0.993 (0.904–1.091)	0.883	1.323 (1.143–0.875)	<0.001*	51.0%	21.4 (1.6–65.5)
EEEO	0.765 (0.650–0.901)	0.001*	1.138 (0.880–1.136)	0.325	43.3%	22.6 (1.9–75.5)
GI	0.894 (0.815–0.981)	0.018*	1.032 (0.896–1.116)	0.663	45.9%	24.1 (2.5–90.1)
Infection	0.991 (0.905–1.086)	0.852	2.062 (1.775–0.563)	<0.001*	45.7%	19.9 (1.3–47.7)
Malign/Immuno	1.054 (0.830–1.337)	0.667	1.484 (0.998–1.002)	0.051	49.2%	22.6 (2.6–66.6)
Muscu & Joint	0.842 (0.724–0.980)	0.027*	1.416 (1.100–0.909)	0.007*	42.3%	23.3 (2.4–68.6)
Nutrition and blood	0.796 (0.729–0.868)	<0.001*	1.022 (0.892–1.121)	0.756	43.9%	24.2 (2.7–89.6)
Obs, Gynae, & Uro	0.791 (0.656–0.955)	0.015*	1.289 (0.953–1.049)	0.100	45.6%	22.9 (2.5–66.1)
Other	0.511 (0.328–0.796)	0.003*	2.521 (0.912–6.969)	0.075	28.6%	9.6 (0.5–42.3)
Respiratory	0.702 (0.634–0.778)	<0.001*	1.246 (1.058–1.468)	0.008*	41.4%	22.3 (1.4–71.2)
Skin	0.579 (0.462–0.727)	<0.001*	1.257 (0.856–1.843)	0.243	35.2%	23.8 (2.5–81.7)

Table 7.8 – Continued

	GEE of Sign-off Rates		GEE of Time to Sign-off ≤48 hours		% Messages Signed-off	Hours to Sign-off (Median, Range)
	Odds Ratio (95% CI)	*p-value*	*Odds Ratio (CI)*	*p-value*		
Regularity of prescription		**<0.001***		**<0.001***		
Regular	1		1	–	50.5%	23.7 (2.5–73.8)
As Required	0.538 (0.495–0.586)	<0.001*	0.813 (0.780–0.935)	0.004*	32.8%	30.9 (3.7–119.9)
Once-Only	0.319 (0.235–0.433)	<0.001*	11.077 (2.581–47.533)	0.001*	22.2%	1.8 (0.1–20.2)
TTO	0.436 (0.397–0.478)	<0.001*	2.818 (2.321–3.421)	<0.001*	29.5%	2.1 (0.3–26.2)
Prescription status		**0.005***		**<0.001***		
Continued	1	–	1	–	47.0%	24.0 (2.5–76.2)
Deleted	0.898 (0.832–0.968)	0.005*	1.739 (1.520–1.989)	0.028*	42.4%	5.3 (0.8–44.1)

*Significant at p<0.05. Results from GEEs accounting for all factors in tables 7.1–7.2, with the exception of Message factors 'Messages assigned to high-risk error' and 'Messages associated with prescription', which were excluded from the analysis owing to multicollinearity. SIGN-OFF: Profession of person signing off the message was excluded from the analysis.

CVS Cardiovascular; CNS Central Nervous System; EEEO Eye, Ear, Nose and Oropharynx; GI Gastrointestinal; Malign/Immuno Malignant Disease and Immunosuppression; Muscu & Joint; Musculoskeletal and Joint Disease; Obs, Gynae, & Uro Obstetrics, gynaecology and urinary-tract disorders

Table 7.9 – GEE results for prescription factors for action rates and time taken to action in ≤24 hours

	GEE of Action Rates		GEE of Time to Action ≤ 24 hours		% Messages Actioned	Hours to Action (Median, Range)
	Odds Ratio (95% CI)	*p-value*	*Odds Ratio (CI)*	*p-value*		
Speciality		**<0.001***		**0.093**		
Medical Admissions	1	–	1	–	44.9%	19.9 (2.2–36.0)
Critical Care and Burns	0.921 (0.718–1.180)	0.515	0.831 (0.585-1.180)	0.301	38.0%	19.7 (0.7–72.6)
General Medicine	1.038 (0.884–1.218)	0.651	0.832 (0.658-1.052)	0.124	37.3%	23.8 (2.2–70.8)
General Surgery	0.750 (0.602–0.934)	0.010*	0.767 (0.551-1.068)	0.116	32.8%	22.1 (1.9–73.4)
Medical Specialities	0.706 (0.610–0.816)	<0.001*	0.857 (0.684-1.073)	0.179	29.1%	20.4 (2.2–48.0)
Surgical Specialities	0.585 (0.483–0.709)	<0.001*	0.714 (0.519-0.981)	0.038	25.9%	24.0 (4.1–90.2)
TNO	1.192 (0.945–1.504)	0.139	0.598 (0.422-0.848)	0.004	38.1%	28.3 (7.2–110.9)
BNF category		**<0.001***		**0.001***		
CVS	1		1		37.5%	23.0 (3.4–68.8)
CNS	1.162 (1.024–1.320)	0.020*	1.205 (0.987-1.471)	0.067	36.2%	21.4 (1.9–54.5)
Endocrine	1.132 (0.944–1.356)	0.180	1.158 (0.879-1.527)	0.297	41.8%	21.7 (2.6–48.1)
EEEO	0.872 (0.646–1.176)	0.369	0.806 (0.499-1.302)	0.378	34.4%	24.5 (4.1–97.4)
GI	0.771 (0.648–0.917)	0.003*	0.941 (0.709-1.249)	0.674	26.1%	23.2 (2.6–75.7)
Infection	1.246 (1.048–1.482)	0.013*	2.055 (1.546-2.732)	<0.001*	37.8%	6.0 (1.2–26.4)
Malign/Immuno	0.918 (0.555–1.519)	0.740	0.958 (0.442-2.075)	0.913	34.6%	23.4 (2.3–51.0)
Muscu & Joint	1.204 (0.888–1.632)	0.232	1.142 (0.713-1.830)	0.580	38.6%	22.0 (2.2–48.2)
Nutrition and blood	0.815 (0.677–0.981)	0.030*	1.116 (0.830-1.500)	0.467	36.2%	21.4 (3.4–51.8)
Obs, Gynae, & Uro	0.892 (0.603–1.320)	0.568	0.921 (0.504-1.682)	0.788	36.9%	23.4 (2.4–44.4)
Respiratory	0.906 (0.734–1.119)	0.358	0.893 (0.645-1.238)	0.498	36.7%	24.0 (2.4–69.6)
Skin	0.546 (0.297–1.005)	0.052	1.493 (0.495-4.501)	0.477	19.5%	19.2 (2.2–54.0)
Regularity of prescription		**<0.001***		**0.468**		
Regular	1		1	–	41.50%	21.6 (2.2–51.6)
As Required	0.374 (0.317–0.442)	<0.001*	0.896 (0.666-1.206)	0.468	18.60%	24.2 (2.2–90.2)

*Significant at p<0.05. Results from GEEs accounting for all factors in tables 7.1–7.2, with the exception of Prescription Factor 'Prescription status' which was excluded from the analysis of action and time to action as this can be considered an outcome. ACTION: Categories with zero counts (BNF category 'Other' and Regularity 'As required' and 'Once-only') were excluded from the analysis. TIME TO ACTION: Categories with zero counts (Communication theme: 'Contraindication', 'Drug Interaction'; 'Drug Selection'; 'Omission' 'Other' and 'Supporting Information' were excluded from the analysis. CVS Cardiovascular; CNS Central Nervous System; Eye, Ear, Nose and Oropharynx; GI Gastrointestinal; Malign/Immuno Malignant Disease and Immunosuppression; Muscu & Joint; Musculoskeletal and Joint Disease; Obs, Gynae, & Uro Obstetrics, gynaecology and urinary-tract disorders.

7.3 Discussion

In this study, thousands of free-text communications were analysed that were written by pharmacists to physicians and sent via the CPOE system in a large acute hospital. The extensive audit system allowed several factors to be considered that might influence the sign-off and action of messages and the time taken.

The low rate of sign-off (n=46.6%) may suggest that this function is not always utilised by the physician as acknowledgment that the information from the pharmacist has been read and/or actioned. Those messages that were analysed for action would be considered interventions by the assigning pharmacist since they requested a "*change in a patient's management or therapy"* (Dooley et al., 2004). A lower rate of action was observed (n=35.8%) than might have been expected compared to other pharmacist intervention studies in the context of CPOE, where acceptance rates have been found to range from 86−90% (Bedouch *et al.*, 2011; Bourne & Choo, 2012; Ibáñez-Garcia *et al.*, 2016). This may suggest that communication via the CPOE system is sub-optimal at the study site and messages are not being received as intended. Alternatively, messages may have been considered by the physician and a decision made that, in the most part, an action was not necessary (Niazkhani *et al.*, 2010). When messages were signed-off or actioned, this did not always occur in a timely manner, with two thirds of messages (65.5%) signed-off within 48 hours and just over half (57.0%) actioned within 24 hours. A delay in the acceptance of interventions has previously been observed when they were requested via a CPOE system compared to verbal communication (Bedouch *et al.*, 2011), which may suggest physicians do not always prioritise medication-related tasks communicated electronically (Brown, 2014).

The findings may be explained by a number of system and process factors, which are discussed below.

7.3.1 Process factors

It is perhaps not surprising that various time-related factors affected the sign-off and action of messages. Over the weekend when the wards are likely to be staffed by a reduced number of physicians, the rate of sign-off was lower and the time taken to both sign-off and action messages was found to increase on Fridays and at weekends. A separate study in the same hospital setting found that junior physicians took significantly less time to generate prescriptions in the CPOE system at the weekend (Coleman *et al.*, 2015). Together with our findings, this may suggest that on-call / covering physicians spend less time interacting with a patient's prescription profile over the weekend or do not prioritise review messages when services are typically reduced both inside and outside the hospital (Freemantle *et al.*, 2015). The delay could also be explained by the physicians' lack of confidence to act on requests without consulting more senior colleagues, or on behalf of another clinical team. The fact that messages communicated on a Friday also took longer to action may relate to the messages being assigned after the consultant ward rounds (which typically occur in the morning); messages may not be seen until the next routine review of the patient. However, a reduction in the presence of ward pharmacists at the weekend (and perhaps in the afternoon) should not be discounted as a contributing factor here; their presence may act as a visual or verbal prompt for physicians on weekdays to pay attention to medication-related tasks and in a more timely manner.

Typically, the longer a prescription had existed for a patient, the longer it would take for a message to be signed-off or actioned. Physicians may enter a patient's PICS profile more frequently to monitor response or to optimise treatment to new prescriptions, increasing the opportunity of seeing a message for an action to occur. The pharmacist may also direct their attention to new orders in their prioritisation of tasks, influencing the time to action with additional verbal requests to the physician as they await a response to their message (Wu *et al.*, 2013). This finding may highlight a need to encourage regular review of all prescriptions during a patient's admission.

The grade of the pharmacist was found to be predictive of both action and action within 24 hours, with physicians less likely to sign-off messages assigned by the highest grade pharmacists, but more likely to action their requests. This factor has previously been found to be a significant predictor of physician acceptance of interventions (Barber *et al.*, 1997). In the UK, grade 6 (relatively newly qualified) pharmacists typically rotate every 3 months to gain experience across a range of specialities. As pharmacists move to higher grades, they are more likely to work within a single speciality and have a more consistent presence on a ward, allowing more time for physicians to better understand and appreciate the knowledge and skills the pharmacist can provide to the team (Liu *et al.*, 2010). This is likely to promote collaborative working, which may influence physicians' response to pharmacists' requests and how these are prioritised.

Messages assigned to high-risk medicines were, perhaps worryingly, less likely to be signed-off or actioned. Although the majority of prescriptions are generated by junior physicians in NHS Hospitals (Lewis *et al.*, 2014), in most cases they are not the decision maker and follow

instructions by senior medical colleagues (Dearden *et al.*, 2015; Ross *et al.*, 2012). As such, the physician may be cautious to make changes to a prescription until consulting more senior colleagues, leaving messages on screen for others in the team to view. However, if this were the case, a delay in the time taken for both outcomes would be expected, which was not observed. In contrast, messages relating to the medicines reconciliation process were more likely to be signed-off and actioned. Given that these requests involve amending a prescription to reflect a patient's 'usual' regimen, the physician is not being asked to make a decision about a new prescription *per se*. As such, they may perceive these as more straightforward and without the need to consult more senior colleagues. The difference in the rate of sign-off and action according to the medicine category may provide further evidence that physicians find certain requests and medications—such as those relating to cardiovascular medicines—easier to take action on, possibly because of their familiarity with the associated regimens. Messages regarding the Dose /Frequency of medicines were significantly more likely to be signed-off compared to all other types of messages, with the lowest rate observed for contraindicated medicines. This finding did not correlate with the action, suggesting that some requests were not deemed necessary. These findings relating to high-risk medicines, medicines reconciliation and the theme of the message, may all be reflective of the prescribers' confidence to alter regimens. This may serve as evidence that electronic communication should only be used for non-urgent requests (Edwards *et al.*, 2009), while others require face-to-face or direct (collaborative) discussion between the pharmacist and the physician, which would provide opportunity to gain more context of the patient and the request.

Finally, there was a significant difference in the rate of sign-off and action according to the specialty the patient was under the care of. At the study site, the Medical Admissions ward—used as the reference category—has fairly consistent staff presence across the day and night compared to the on-call cover systems on medical and surgical wards. A pharmacist is present all day Monday–Friday on this ward (as they are for Critical Care and Burns), unlike Surgical Specialities where the pharmacist will visit on a daily basis, but will not be present all day. Physicians are likely to be more familiar with the pharmacist in these settings and as such a mutual understanding of each other's expectations regarding medication-related tasks is likely to have developed. For example, the pharmacist may actively encourage physicians to engage with the review messages before the end of their shift. A low acceptance rate of interventions has previously been observed in a hospital where the pharmacists communicated entirely via the CPOE system and did not participate in ward rounds (Estellat *et al.*, 2007). Adopting a process of minimal face-to-face communication would not be considered collaborative, or promote such working. In contrast, a study investigating the impact of CPOE in the "*team-orientated*" Critical Care setting found it did not have a negative impact on the quality of communication in the long-term (Hoonakker *et al.*, 2013).

7.3.2 System factors

Review messages in PICS may be considered a type of alert to the physician, albeit a passive one that is non-interruptive. Human factor variables found to influence acceptance of alerts are: 1) display characteristics (i.e. proximity of the alert to the event); 2) textual information; and 3) prioritisation (Seidling *et al.*, 2011). The sign-off function is intended to serve as an

indication that a message has been received, read and acknowledged. However, the rate of sign-off would indicate that it may not be used as intended. A failure to sign-off a message means it remains on a patient's prescription order and as such, may unnecessarily contribute to a message burden on screen. This may have an unintended consequence of reducing the effectiveness of messages, with new messages indistinguishable from the old. Messages may become invisible or are no longer obvious to the physician and so may be overlooked (Caruba *et al.*, 2010; Estellat *et al.*, 2007). This may provide some explanation as to why a large majority of messages were signed-off by pharmacists themselves (39.3%, n=6,302/16,025), actively removing the 'R' icon from the screen on the physicians' behalf to ensure any remaining messages still require acknowledgement. This finding suggests that further training is required to promote optimal use of the system—interprofessional sessions would also enable practitioners to share their expectations on the use of the system.

In PICS, a pharmacist is unable to assign a priority to a review message to identify those that require more urgent acknowledgment or response. Without this information the physician is unable to appropriately prioritise medication-related requests over other tasks. This may provide some explanation for the observed delay in the sign-off and action of some messages. On the other hand, it was reassuring to find that messages assigned to anti-infective medicines were more likely to be actioned within 24 hours compared to other medicines. Again this suggests that physicians prioritise the review of some medicines over others; in the particular case of anti-infectives, it may be as a result of national campaigns to raise awareness of antimicrobial stewardship (Department of Health, 2015).

The review message function does not allow for bi-directional communication and so the physician is not obliged to respond in order to gather information about the query. Therefore, aside from signing-off a message, the physician cannot provide an explanation for their subsequent action (or inaction). CPOE systems with CDS software that allows clinicians to provide an explanation as to why alerts have been over-ridden have been found to be more likely to succeed than those that did not (Roshanov *et al.*, 2013). Therefore designing systems with bi-directional communication may increase the physician's awareness of messages, which over time could inform its optimal use. For example, it may reduce the total number of messages assigned by pharmacists as they understand what information is useful to the physician and how best this should be communicated. Two-way communication would also increase collaborative working, integral to the effectiveness of this modality of communication.

7.3.3 Strengths and limitations

The aim of this study was to investigate the effectiveness of pharmacist-physician communications when sent via a CPOE system. As previously described (see 6.3.1), a strength of this study is the size of the database, with over 34,000 messages available for analysis, 16,025 of which were eligible for analysis of time to sign-off and 9,991 for action. The language used by pharmacists in their written discourse was not analysed in this study. This may change depending on the grade or prior experience of the pharmacist (Liu *et al.*, 2014) and could provide further explanation for the outcome of communications in this study.

In the analysis, prescribing errors were not identified, since this would have required assumptions to be made of the data without context of the patient or the situation at the time. Therefore only those messages analysed for action can be directly compared to intervention studies. Further targeted qualitative research is required to understand why messages are not consistently signed off or actioned in PICS and why the function does not appear to be used as intended by system developers.

7.3.4 Conclusions

The capability to communicate in an *ad hoc* asynchronous manner in hospital has benefits for both the pharmacist and physician—fewer interruptions reduce the need for the physician to multi-task, which can reduce procedural and clinical errors in a busy and pressured environment. However, in this study a lower rate of sign-off and action was observed than might have been expected, suggesting uni-directional communication via the CPOE system may not be optimal. An established pharmacist-physician collaborative working relationship is likely to influence the prioritisation and response to messages, since a more desirable outcome was observed in settings and with grades of pharmacists where this was more likely. Designing systems that can facilitate collaborative communication, such as with the ability for the physician to respond, may be more effective in practice.

Chapter 8 A QUALITATIVE ANALYSIS OF PHARMACIST-PHYSICIAN COMMUNICATIONS IN A HOSPITAL CPOE ENVIRONMENT

In this chapter, I describe the qualitative research methods used to investigate communication between pharmacists and physicians at UHBFT and Guy's and St Thomas' NHS Foundation Trust. I introduce five themes that emerged from the analysis of the data and consider these in relation to the communication load of pharmacists and the effectiveness of communication. Finally, I interpret the findings in the context of the literature and propose new ideas to explain why CPOE was found to impact on communication between the professional groups.

8.1 Background and research questions

Healthcare has been described as a *"complex adaptive system"* (Plsek & Greenhalgh, 2001; Sturmberg *et al.*, 2012), where staff will adapt very quickly in response to changes such as new technology and will organise their work so that they can continue to meet targets and achieve desired outcomes. It is strongly recommended that healthcare organisations work closely with designers and suppliers when planning to implement new technology such as CPOE. This ensures that staff are effectively engaged in the process from the start and can

consider the local environment in the design and implementation (Cresswell *et al.*, 2013a; Gagnon *et al.*, 2014). During this process, the organisation will have considered the benefits of implementing the new technology, such as on safety and productivity, but the sociotechnical implications are often harder to predict. *"Work as intended"* and actual *"work as done"* (Blandford et al., 2014) can be very different in practice and are not easily identifiable from the analysis of quantitative data generated from CPOE systems. Examining the sociotechnical factors associated with the implementation of new technology allows the intended and actual use to be better aligned.

Qualitative research methods enable the context of the hospital environment to be considered when evaluating the impact of new technology. This includes the organisational, professional and social factors that can impact on the use and acceptance of new systems (Boonstra & Broekhuis, 2010; Kaplan, 2001). The methods allow us to determine how and why sociotechnical factors may change or evolve over time, by examining the habitual adjustments staff make (consciously or unconsciously) to continue to achieve the desired outcomes as the technology embeds into the culture of the organisation.

The aim of this study is to explore pharmacists' and physicians' perceptions of their interprofessional communication in the context of CPOE and CDS and to validate the findings using ethnographic non-participant observation.

The analysis will be framed by known topics from a systemic review of the literature described in Chapter 2 (Thomas & Coleman, 2012) and the quantitative analysis described in Chapters 5–7 (Pontefract *et al.*, 2016).

8.2 Method: Focus Groups

8.2.1 Methodological approach

There are two potential research methods available for generating qualitative data to meet the objective of this study: interviews and focus groups. Focus groups were selected as the method for gathering the data. Unlike one-to-one interviews, focus groups allow for data to be generated on the collective views of participants (Morgan, 1998a; pp 9-16). Opinions and experiences of participants can be shared within a group discussion and contextualised to determine similarities or differences. This is important given that the subject being investigated is the direct or indirect communication between two professional groups. Since pharmacists and physicians work alongside each other as part of the healthcare team, participants should also feel that they can talk openly, avoiding the need for interviews to be conducted separately to avoid conflict.

8.2.2 Ethics approval

This study protocol received favourable opinions and approval by the Research and Development Department at both UHBFT [21st October 2013] and Guys and St Thomas' NHS Foundation Trust [27th August 2015]. The study was also approved by the University of Birmingham Ethics Committee [ERN_12-0127].

8.2.3 Data collection

8.2.3.1 Setting

Focus groups were conducted with pharmacists and physicians in two hospitals sites: UHBFT, the setting of the quantitative study described in Chapters 5-7; and Guy's and St

Thomas' NHS Foundation Trust (GSTFT). The latter comparator site was selected, based on the pre-defined criterion that the hospital had recently (within the last 12 months) implemented a CPOE system.

University Hospitals Birmingham NHS Foundation

As previously described, UHBFT uses a locally developed CPOE system called PICS, which has been in use at the hospital since 2004, although earlier parts of the system existed as early as 1998 (Nightingale *et al.*, 2000). PICS is used for the prescribing and administration of medicines throughout all inpatient beds, with the exception of the Emergency Department and some complex systemic anticancer therapies prescribed according to defined treatment protocols. It is also used to generate the discharge summary and prescription for patient discharge (known as 'to take out' prescriptions, or TTOs). Despite being highly digitised, with PICS holding pathology data and documentation of vital observations (e.g. blood pressure) and clinical assessments, the medical notes remain paper-based throughout the hospital.

Guys and St Thomas' NHS Foundation Trust

Despite a digital drive for NHS hospitals to become paperless, very few hospitals implemented CPOE during the period of this overall programme of study. The GSTFT was identified through the National Institute for Health Research programme grant for applied research, '*Investigating the adoption, implementation and effectiveness of electronic prescribing systems in English Hospitals*' [RP-PG-1209-10099]. As it was known that the Trust had recently implemented the system, the electronic prescribing pharmacist was contacted and invited to participate in the study.

In contrast to UHBFT, GSTFT have three commercial CPOE systems in use across the hospital. The Intensive and High Dependency Care Unit (ICU) was the first department to digitise the prescribing process, implementing the CareVue® electronic patient record in 2004. The discharge process across the hospital was next to be digitised in 2006, with all discharge prescriptions generated using the iSoft® system. Lastly, between 2014 and 2015 the MedChart® system was implemented for all other inpatient departments. A summary of the technology used in each site is provided in Table 8.1.

Table 8.1 – Summary of electronic patient records available at UHBFT and GSTFT

Description	UHBFT	GSTFT
CPOE system	PICS	CareVue®; MedChart®, iSoft®
Commercial or 'home grown'	Home grown	Commercial
Electronic discharge	PICS	iSoft®
Medical notes	Paper-based	*ICU:* Electronic and integrated in CareVue® *Rest of hospital:* e-Noting separate to MedChart®
Electronic messages to individual patient prescription item	Yes	No
Other function to communicate with physician	Nil	Alerts that can appear when the physician generates a prescription
Simultaneous access	Staff can access records and make changes in the system at the same time	Staff can access the system at the same time, but are unable to make changes at the same time
Pharmacist proposing of prescriptions	Can propose prescriptions for physician authorisation	Can propose prescriptions for physician authorisation

8.2.4 Participant recruitment

Pharmacists and physicians were eligible to participate in the study provided they were qualified in their field and had regularly prescribed or validated inpatient prescriptions within the CPOE system within the preceding six months. For both professions, no restrictions were placed on the grade of the professional or number of years of experience. Between 6–8 participants was set for each focus group, to allow for discussion to be generated and for everyone to have an opportunity to contribute in the allocated time (Morgan, 1998b; pp 71-73).

Both pharmacists and physicians were invited to participate in the study via email. The email provided a background to the research question, dates that the focus group(s) would be held on and a copy of the Participant Information Leaflet for further information (Appendix 13). This ensured that potential participants were appropriately informed and could ask questions prior to accepting the invitation, or had the opportunity to prepare questions to ask before the focus group commenced. In both sites, emails were sent by members of staff who were familiar to the professional groups. At UHBFT, physicians were emailed directly by the Postgraduate Centre Manager for Education and the pharmacists by the Deputy Director of Pharmacy. At GSTFT, the Deputy Director of Pharmacy (the nominated research facilitator required by the hospital for research and development approval) emailed potential participants. In each case, I was copied into emails so that potential participants could respond to me directly and ask any questions.

8.2.5 Consent

At the beginning of the focus group, participants were provided with another copy of the Participant Information Leaflet, along with a Consent Form and given some time to read these to ensure they were fully informed about the research. Participants were asked to acknowledge that they had read and understood all the information presented in the Consent Form by initialling each of the statements listed (Appendix 14). The same Content Form and Participant Information Leaflet was used for all four focus groups as the focus of the research did not change throughout the study.

8.2.6 Conducting the focus groups

Topics identified through the systemic review of the literature described in Chapter 2 (Thomas & Coleman, 2012) and the quantitative analysis described in Chapters 5–7 (Pontefract *et al.*, 2016) were listed in a guide for the facilitators, along with related prompt questions and the overall research question (Table 8.2). This ensured that specific topics were integrated into the discussion and could be used to refocus *"off-topic remarks"* (Gubrium & Holstein, 2001; pp 147) that were not related to the research.

Table 8.2 – Topic guide to facilitate the conducting of the focus group

Theme	Example of questions
Unidirectional communication	[Physician] What are your thoughts on the review message function for conveying medication-related information? [Pharmacist] Can you tell me about any methods you might use to check that the information communicated within the review message has been received as intended?
Interpersonal communication	What are your thoughts on the frequency of interpersonal communication between the pharmacist and the physician?

Electronic messages	What are your thoughts on the electronic message in terms of conveying urgency of the communication?
Physician accessibility to electronic review messages	What are your thoughts on the accessibility of the review message within the PICS system?
Clinical decision support	[Pharmacist] Can you tell me whether you think/feel that the presence of CDS affects the type of information you communicate to the physician? [Physician] Can you tell me your thoughts on how the presence of CDS might affect the messages received by pharmacists?
Acknowledgement of messages	[Pharmacist] What are your thoughts on how messages are 'signed-off' (acknowledged) within PICS? [Physician] Are there any instances where you might consider leaving the message on screen and not signing it off?

Four focus groups were conducted across the two sites; three at UHBFT and one at GSTFT (Table 8.3). Both uni-professional and mixed focus groups were conducted at UHBFT, each with a range of professional grades. The focus group at GSTFT was conducted at a later date to allow some time for a preliminary analysis of the data to be conducted and for observational research to be performed at UHBFT (see section 8.3).

Table 8.3 – Demographics of the focus groups

Focus group	Date	Setting	Professional group
1	16th June 2014	UHBFT	Pharmacists
2	23rd June 2014	UHBFT	Physicians
3	1st July 2014	UHBFT	Pharmacists and Physicians
4	25th Feb 2016	GSTFT	Pharmacists and Physicians

It is important to consider the composition of focus group participants in the research design process, as the data generated by the interaction between individuals is dependent on the group dynamic (Kitzinger, 1995). The uni-professional focus groups allow for similar or shared experiences to be discussed between participants and to explore issues in more depth. In this case, the views on communication with the other professional group may also be expressed openly without fear of offending someone. However, although the uni-professional groups may appear homogenous (i.e. same professional training), introducing participants with a range of experience to a single focus group also provides an opportunity to discuss how opinions and perspectives differ and how these may have been influenced over time. The introduction of mixed focus groups, which in this case sees two different professional groups interact, provides an opportunity for participants to discuss the barriers and facilitators to communication and to challenge each other's views. In each case, the group interactions allow for views to be challenged, debated and even rationalised among the group and may even lead to changes in views as a result (Kitzinger, 1994).

I moderated the four focus groups. This involved opening and directing the discussion, ensuring all participants had the opportunity to participate and that the discussions were not dominated by any individual(s) in particular. In addition, interruptions would be prevented or minimised to avoid problems with audio recordings and transcription (Fern, 1982; Gubrium & Holstein, 2001; pp 146). Each of the focus groups was facilitated by an independent academic researcher, known to me as staff at the University (CH at UHBFT and SS at GSTFT). Conscious of my background as a pharmacist and having occasionally worked at UHBFT, independent facilitation was important to ensure that I did not inadvertently lead the discussion, which could potentially lead to confirmation bias in both the analysis and

interpretation of the data (Mays & Pope, 2000). The facilitators were selected based on their previous experience of qualitative research, their understanding of the role of the hospital pharmacist, knowledge of CPOE systems and, their independence from the study site. They were provided with a background to the study, had explained to them any common terms that may emerge during the focus group (e.g. CPOE terminology) and were provided with the topic guide (Table 8.2) to facilitate the discussion. A second independent academic member of staff (HB at UHBFT and HV at GSTFT) was also present in the groups to undertake administrative tasks of collating signed consent forms, setting up the recording equipment and taking notes to facilitate transcribing of the data.

Prior to the start of the focus group, an opportunity was provided for any final questions to be asked of the moderator. The recorder was started and it was further reiterated that participants were free to leave at any time and that everyone had consented to the focus group being recorded. The aim of the study was repeated and the moderator, facilitator and administrator introduced themselves and explained their role in the process. Participants were then asked to introduce themselves by providing the following information:

i. Profession (pharmacist or physician);
ii. Number of years qualified; and
iii. Previous experience with paper-based prescribing process (Yes/No).

Every focus group commenced with the same opening question to "*capture the interest of the participants"* (Gubrium & Holstein, 2001; pp 148); this was broad and related to the overall research question:

> "*What are your thoughts on communicating with the [physician /pharmacist/each other] in the context of electronic prescribing"*?

Each focus group lasted between 1–1.5 hours and was recorded so the data could be transcribed at a later date.

8.2.7 Peer debriefing

Immediately after each focus group, the moderator, facilitator and administrator gathered to reflect on and discuss the interview in a debriefing meeting (Table 8.4). The debriefs were conducted to discuss the organisation and running of the focus group, whether any aspects needed be improved for subsequent groups and to discuss the interpretation of the data to probe its relevance to the research question (Given, 2008; pp 603-605). In each case, any topics identified that may warrant further discussion were documented and added to the topic guide to focus data collection for subsequent groups. A second debriefing was also conducted after each focus group with the academic qualitative supervisor. In addition to discussing the above points and gaining feedback, this particular debrief provided further opportunity to discuss initial thoughts and impressions, identify any gaps in the data and begin the process of analysis and interpretation.

Table 8.4 – Dates of peer debriefing following focus groups

Focus group	Date of focus group	Date of debrief 1*	Date of debrief 2*
1	16th June 2014	16th June 2014	17th June 2014
2	23rd June 2014	23rd June 2014	27th June 2014
3	1st July 2014	1st July 2014	23rd July 2016
4	25th Feb 2016	25th Feb 2016	29th Feb 2016

*Debrief 1: facilitator and administrator; Debrief 2: Academic supervisor (Sabi Redwood)

8.2.8 Data analysis

Focus group data were transcribed verbatim, but did not take account non-verbal communication such as laughter. Participants were anonymised using a letter to represent their profession (P: Pharmacist; D: Doctor), a number to identify the statements of individuals and a letter to represent the location (B: UHBFT; G: GSTFT). Prior to any formal coding of the data, each of the transcripts was read in full and on multiple occasions to become familiar with the content. Initial thoughts and reactions to the data were documented and early ideas about connecting themes were noted using mind maps. This early process of analysis was important to understand the dataset as a whole, which would facilitate formal coding and thematic analysis at a later date. The transcripts were uploaded into NVivo 10, a Computer Assisted Qualitative Data Analysis Software designed to facilitate coding and theming of such data. The following attributes were assigned to each focus group and the individual participants so that, where applicable, the characteristics may be considered when comparing concepts during the analysis:

- Setting (UHBFT or GSTFT);
- Profession (pharmacist/physician);
- Length of time qualified (<1 year, 1–3 years, 4–10 years, more than 10 years); and

- Experience with paper-based prescribing systems (Yes/No).

The data were analysed using an integrative method of both deductive and inductive analysis. The deductive approach was conducted using a framework of codes (Table 8.5) that were identified from both a systematic review of the literature described in Chapter 2 (Thomas & Coleman, 2012) and the quantitative study of pharmacist-physician communications described in Chapters 5-7 (Pontefract *et al.*, 2016). This framework analysis enabled already known concepts to be integrated into the analysis (Bradley *et al.*, 2007).

Table 8.5 – Framework to inform deductive analysis of focus group data

Origin of theme	Theme
Systematic review	A false communication Interpersonal communication The impact of pharmacist messages in an electronic format Physician accessibility to pharmacist alerts The effect of CDS on communication
Quantitative analysis	Pharmacist assignment of review messages Physician action of review messages

An inductive analysis of the data was conducted to identify new or emerging concepts that had not already been highlighted during the research. This was particularly important given that few studies had been identified in the initial review of the literature (Chapter 2). In the analysis, the data were initially fine coded to capture detailed descriptions of the data. The codes were then arranged into the most salient or common themes that were observed across all four focus groups and all participants in the analysis (Green & Thorogood, 2009; p198-199).

8.2.9 Confirmability: verification of codes

Approximately one quarter of the text data from two focus groups were selected at random from UHBFT (uni-professional; pharmacists) and GSTFT (mixed; pharmacists and physicians). An academic qualitative researcher with an interest in CPOE and medication safety (SS), was asked to review the transcripts with the research question in mind and apply codes to describe the data. The codes were then discussed and compared with the themes and codes already generated.

The approach taken to request that a proportion of the transcripts were coded by an independent researcher was not conducted to guarantee validity of the analysis (Cook, 2012), but to provide an insight that may be useful for checking methodological or confirmation bias. Importantly, it provided an opportunity to discuss and refine the descriptions used for codes and themes going forward.

8.2.10 Transferability of the findings

Optimising the transferability of the findings was considered in the design of the focus group research. First, participants in both sites were randomly selected to participate in the study and with a range of professional grades so that the sample could be more representative of a larger population of professionals in each site. Second, GSTFT was selected as a contrasting site to UHBFT in relation to: the CPOE systems in use; the relative length of time it had been in use; and, the lack of functionality for pharmacists to communicate requests and information electronically assigned to a prescription. Importantly, comparing sites that had adopted CPOE technology at different times allows

for the *"stability and change in sociotechnical relations"* to be investigated (Pollock & Williams, 2010), helping to identify short and long-term impacts of implementing new technologies, such as with adjusting professional roles and routines.

GSTFT was also selected based on its shared features with UHBFT in: providing care for acute inpatients; the provision of specialist services (e.g. critical care); and, presence of ward based pharmacists. The distinct similarities and differences were intended to allow for emerging concepts to be compared between sites to inform interpretation of the data (Green & Thorogood, 2009; Silverman, 2016).

8.3 Method: Non-participant observation

8.3.1 Methodological approach

Qualitative observational research in the context of health information technology can allow for the dynamic between social and technical processes to be investigated across a range of dimensions, including the hardware and software, human-computer interaction and workflow and communication (Siting & Singh, 2010). Observation was therefore selected as a means of data triangulation to compare and further explore the findings from the quantitative study of pharmacist-physician communications at UHBFT (Chapters 5–7) and the themes identified from a preliminary analysis of the focus group data at the same site (Reeves et al., 2008; Mays & Pope, 2000). Observational research can be conducted overtly, where there is a mutual understanding between the observer and participant regarding the aim of the study, or covertly where the opposite is true (Mays and Pope 1995). Given that pharmacists and physicians at the study site had been invited to participate or had

participated in the focus groups, overt observation was necessary. Pharmacists were selected as participants because they instigate the use of the review message function at UHBFT and data from the focus groups suggested that their requests are frequently followed up directly with the physician. Although observation of the physician would be valuable to gain an insight into their response to the messages via the CPOE system, there was concern that conducting this overtly could alter the behaviour of the physician—the so called "*Hawthorn effect*"—with a potential to impact on the validity of the findings (Roethlisberger & Dickson, 1961, cited in Goodwin et al., 2017). In addition, since the receipt and review of messages sent by the pharmacist is one of many tasks potentially carried out by the physician on a daily basis, the observation time dedicated to the study would need to be substantially increased to capture a degree of interaction with the messages that could facilitate exploration.

8.3.2 Ethics approval

This study protocol received favourable opinion and was approved by the Research and Development Departments at both the UHBFT [21st October 2013] and GSTFT [27th August 2014]. The study was approved by the University of Birmingham Ethics Committee [ERN_12-0127].

8.3.3 Data collection

Pharmacists were observed performing their routine clinical duties in the hospital setting at UHBFT. Observations were particularly focused on the pharmacists' use of the review message function, documentation of information to coordinate care with other staff and general interactions with physicians.

8.3.3.1 Setting

Two broad settings were selected for the study, where pharmacists spend the majority of their time: the wards and the dispensary.

Wards

Pharmacists at UHBFT are predominately ward-based and each is responsible for a number of named wards that they will visit every weekday. Grade 6 pharmacists are responsible for named wards for a period of approximately three months and grade 7 pharmacists for four months. Pharmacists spend the majority of the day covering their allocated wards, although most grade 6 pharmacists are generally required to return to the dispensary from 16:00 onwards (although there are exceptions to this, specifically if they are assigned to the Admissions or Oncology wards). The total time spent on the wards can vary depending on the number of wards a pharmacist is required to cover in the course of a day, taking into account additional wards that they may need to visit to cover annual leave. The ward pharmacists spend their time reviewing patients' prescriptions generated in PICS, undertake or confirm medication histories and communicate with other members of the healthcare team about medication-related issues. To gain an insight into how the pharmacists' tasks and role may differ across specialities, observations were scheduled on a range of wards: Admissions; General Medicine; Critical Care; Liver and Renal.

Dispensary

Pharmacists are required to spend some time in the dispensary on a weekly basis. This would typically be for one of four designated time slots on one day in the working week

(Table 8.6). To gain insight into how the time of day may impact on the pharmacists' tasks, each of the above time slots were planned to be observed at least once.

Table 8.6 – Pharmacist cover in the dispensary, divided into four time slots

Time	Description of pharmacist cover
09:00-11:00	The morning is generally covered by one senior pharmacist of at least grade 7
11:00-13:00	One pharmacist will generally be allocated to cover this time slot, unless it is very busy and with exception of a Thursday when two pharmacists will be present. At 13:00 on a Thursday, junior physicians attend periods of protected study and as such are not available to be contacted. Two pharmacists are allocated prior to this to ensure workload can be managed and any queries chased with the physicians beforehand.
13:00-15:00	Generally covered by one pharmacist of at least grade 7, except for when it is very busy
15:00-17:00	Often two or three pharmacists to manage workload prior to the end of the working day

In this dispensary, pharmacists spend their time on the following clinical tasks:

- Missed doses: PICS can highlight when a patient has missed a dose of a medication and generates an order to be automatically printed in pharmacy. It is the responsibility of the pharmacist to manage these orders by checking that the prescription is appropriate before the medication is supplied and ensuring that the missed doses are dealt with in a timely manner;
- Discharge prescriptions (TTO): the pharmacist will check that the prescription is complete and appropriate for the patient;
- General out of stock (non-urgent) medicine request;
- Non-stock requests: from wards that do not have a pharmacist assigned; and,

- Requests for stock requests from off-site departments: (e.g. hospices, rehabilitation units).

8.3.4 Participant recruitment

As for the focus groups, pharmacists were eligible to participate in the observation study providing they were qualified in their field and had regularly prescribed or validated inpatient prescriptions within the hospital CPOE system within the preceding six months. There were no restrictions placed on the grade of the professional or number of years of experience. Pharmacists were invited to participate in the study via email, which was sent from the Deputy Director of the Department. Since the observational research planned was to be overt in nature, the email provided a background to the research question and a copy of the Participant Information Leaflet for further information (Appendix 13). This ensured that potential participants were appropriately informed and could ask questions prior to accepting the invitation or had the opportunity to prepare questions to ask before the observation commenced. The email also detailed the period of time over which the observations would ideally take place. I was copied into the email so that potential participants could respond to me directly and ask any questions. Participants were selected to ensure that a range of professional grades, wards (specialities) and shifts (time of day) could be observed.

8.3.5 Consent

Approximately one week before the observations were planned to commence on the wards, the relevant ward managers were emailed to inform them about the research and to

request permission to conduct the observation. The email provided a background to the research question, the planned time for the observation and attached a copy of the Participant Information Leaflet for further information. In addition, all pharmacy staff (including pharmacists, technicians, administrators and technical officers) were informed about the research during a pharmacy team briefing. It was made clear that the observations would not be filmed or recorded and that written field notes taken would not contain any patient information. It was also explained that the research was funded by the National Institute for Health Research and that the study had been approved by the Trust Research and Development Department.

Prior to the observation commencing, the pharmacist participant was given the opportunity to read the Participant Information Leaflet and ask any questions. It was explained that they were being observed for their workflow, communication and interactions with other healthcare professionals (mostly physicians). It was also emphasised that individual performance was not being assessed and that written field notes would be taken during the observation, but that these would not include any patient data and that the observation would not be filmed or recorded. Finally, it was explained to the participant that they may withdraw from the observation at any stage and that they could request to have any information from the observation removed from the analysis without repercussion. Verbal consent was confirmed from each participant before the observation commenced.

In any situations where a patient was present during the observation of the pharmacist, the observer introduced themselves and explained that they were a researcher observing the

pharmacist on the ward and requested verbal consent to continue. If there was a situation where the patient objected, the observer would remove themselves from the consultation.

8.3.6 Conducting the observation

The aim of the observational research was collect data that could be used to triangulate the findings from the quantitative study and the focus group. A total of 21 hours was planned over 11 days across the two settings at UHBFT, with the intention that this could be increased if new concepts emerged that needed further investigation. I conducted the observations along with two academics from the University of Birmingham: HV, a pharmacist who had previously worked at UHBFT; and HB, a research associate with a background in investigating CPOE and patient safety who had previously acted as an administrator for the focus groups. Multiple observers were selected to collect data to improve the reliability of the study (LeCompte & Goetz, 1982) since it allowed for different perspectives to be gained. Importantly, this also enabled more hours of clinical time to be observed. The participants were cognisant of the research question and aims. The observers were informed that they could also share their professional background with the participant and could interact to ask questions to gain context or further explanation of events as needed. However, participants were not formally interviewed and recorded.

In both the ward and dispensary setting, the observations were targeted (Table 8.7 and 8.8) to look for concepts that were identified in the quantitative study described in Chapter 5–7 (Pontefract *et al.*, 2016) and from the preliminary analysis of data generated by the focus groups. However, observers were also informed that they could document observation that

they felt were relevant to pharmacist-physician communication that had not already been identified and described to them.

Table 8.7 – Themes for targeted ethnographic observation on the wards

WARDS		
Theme	Sub-theme	Example
Interpersonal communication	Synchronous communication	Synchronous communication (or attempts made to) with the physician (i.e. both the pharmacist and physician participating in the communication at the same time, e.g. face-to-face)
		Difficulties getting hold of the physician
		Informing a physician about a review message being placed on PICS for their attention
		Communication from the physician
	Asynchronous communication via PICS	Communication via the review message
		Communication in the medical notes
	Collating tasks to handover to the physicians	Process of collecting tasks over a period of time to handover in a single interaction
Theme of communication	Clinical decision support	Errors generated by default orders
Documentation	Pharmacist messages for communicating with other pharmacy staff	Time spent on task, duplication of tasks
	Use of the P-note (endorsement)	Use of P-note to document information
Proposals	Pharmacist use of the proposal function	Frequency of medicines being proposed
		Informing physician of medicines proposed
Professional roles (t**raining**)	Pharmacists as informal trainers of the system	Being asked about how to use PICS

Table 8.8 – Themes for targeted ethnographic observation in the dispensary

DISPENSARY		
Theme	Sub-theme	Example
Interpersonal communication	Synchronous communication	Synchronous communication (or attempts made to) with the physician (i.e. both the pharmacist and physician participating in the communication at the same time, e.g. face-to-face) Difficulties getting hold of the physician Informing a physician about a review message being placed on PICS for their attention Communication from the physician
	Asynchronous communication via PICS	Communication via the review message Difficulties getting hold of the physician
Theme of communication	TTO supply problems, controlled drugs prescription problems	Incomplete controlled drug prescriptions that require handwritten annotation
Closing the loop of communication	Pharmacist following up on whether interventions have been actioned	Method adopted and frequency conducted
Professional roles (training)	Pharmacists as informal trainers of the system	Receiving phone calls from physicians to find out how to use PICS

Observers were reminded to observe and record a range of dimensions of observation, such as: *"objects"* (e.g. availability of hardware); *"activities"* (of staff); *"actions"* undertaken by a member of staff; *"goals"* of the healthcare professionals at work; and "feelings" expressed by participants or those around them (Spradley, 1980, cited in Reeves *et al.*, 2008). An 'Observer' badge was worn throughout each observation. In the ward setting, the observer introduced themselves to the nurse in charge to remind them of their presence and that the observation had been permitted by the ward manager. At the start of each observation period, the start time and the setting (ward name /dispensary) were documented along with the grade of the participant. During the period of observation, the observers made written notes to document their perspective of the events observed (Pope, 2005), along with their thoughts and reflections of the setting and interactions within it and, where applicable, the perspectives of those observed. The observers were informed that they could take recording equipment, but that this should only be used to record any immediate reflections when the observation had finished.

Each observation was planned to last approximately two hours and at the end of the observation, the finish time was documented so that a total time could be calculated. The observers typed up their notes along with any recorded reflections, as soon as possible after each session.

8.3.7 Peer debriefing

The observers attended regular debrief meetings to discuss and reflect on what they had observed and experienced. This provided an opportunity to discuss the targeted themes, any new dimensions, disconfirmations to the themes and for the observers' to provide their

own interpretation of the data. This part of the process was particularly important given that multiple observers were conducting the research. The debrief meetings also provided an opportunity to discuss the organisation and running of the observations, raise any ethical issues or problems encountered and any aspects that may need to be improved for subsequent observations. Debrief meetings were also conducted with the academic qualitative supervisor to discuss the above points.

8.3.8 Data analysis

The observers' typed field notes and reflections from each observation were uploaded into NVivo 10 to facilitate analysis. The following attributes were assigned to each source:

- Observer initials (SP, HB, HV);
- Grade of the pharmacist participant (6,7,8); and,
- Setting (ward speciality, dispensary).

Since the observational study was primarily conducted to triangulate the findings from the quantitative study and focus group study, the data were analysed into the themes and sub-themes identified in section 8.2.8 to corroborate, explain or refute the findings.

8.4 Results

8.4.1 Participants

A total of 27 people participated in the focus groups across the two hospital sites, 20 at UHBFT (B) and 7 at GSTFT (G). There were 16 pharmacists and 11 physicians (see Table 8.9) and the majority of participants (n=21/26) had worked with paper-based prescribing

systems in the past. The participants varied in their level of experience, from relatively newly qualified pharmacists and physicians who had been qualified for less than 2 years (n=8), to those who had been practising for 2–3 years (n=5), 4–10 years (n=9) and for more than 10 years (n=5) in their professional role. A full summary of the participant demographics is provided in Appendix 15.

Table 8.9 – Demographics of focus group participants

	UHBFT	GSTH	Total
Pharmacists			
No. of pharmacists	11	5	16
Experience with paper-based prescribing	10	5	15
Length of time qualified:			
<2 years	2	0	2
2–3 years	3	1	3
Qualified 4–10 years	3	3	7
Qualified >10 years	3	1	4
Physicians			
No. of physicians	9	2	11
Experience with paper-based prescribing	4	2	6
Length of time qualified:			
<2 years	5	0	5
2–3 years	1	0	1
4–10 years	2	1	3
>10 years	1	1	2

At UHBFT, 15 pharmacists who were eligible to participate in the study were observed for a total of 20 hours, 7.25 hours of which were in the dispensary and 12.75 on the wards (Table 8.10).

Table 8.10 – Setting, participant grade and hours of observation at UHBFT

Setting	Description of setting	Observer	Grade of participant	Date	Time (hours)
Dispensary	09:00–11:00	SP	Grade 8	23rd Feb 2015	2.0
	11:00–13:00	HV	Grade 6 Grade 7 Grade 8	24th Feb 2015	1.75
	13:00–15:00	SP	Grade 6 Grade 8	25th Feb 2015	1.50
	15:00–17:00	HB	Grade 8 Grade 8	27th Feb 2015	2.00
Subtotal					7.25
Ward	General Medicine	HV	Grade 6	26th Feb 2015	2.00
	General Medicine	SP	Grade 6	26th Feb 2015	1.50
	Critical Care	HB	Grade 7	2nd Mar 2015	1.50
	Renal/Liver	HV	Grade 8	2nd Mar 2015	2.00
	Admissions	HB	Grade 7	5th Mar 2015	2.00
	Liver/GI	SP	Grade 7	5th Mar 2015	1.75
	Admissions	SP	Grade 6	10th Mar 2015	2.00
Subtotal					12.75
Total observation time					20.00

GI: Gastrointestinal

All three professional grades of pharmacists were observed, with more grade 8 pharmacists observed overall (n=6), the majority of which were seen in the dispensary (n=5). Equal numbers of grade 6 (n=3) and grade 7 (n=3) pharmacists were observed on the wards. Each of the four allocated time slots in the dispensary were observed once, along with a range of specialities on the wards: General Medicine (3.5 hours); Admissions (3.75 hours); Critical Care (1.5 hours); and, Renal/Liver/GI (4 hours).

8.4.2 Thematic analysis

In the analysis of focus group and observational data, five prominent themes emerged: Professional roles; Interpersonal communication; Documentation; Flow of information; and Decision-making (Figure 8.1).

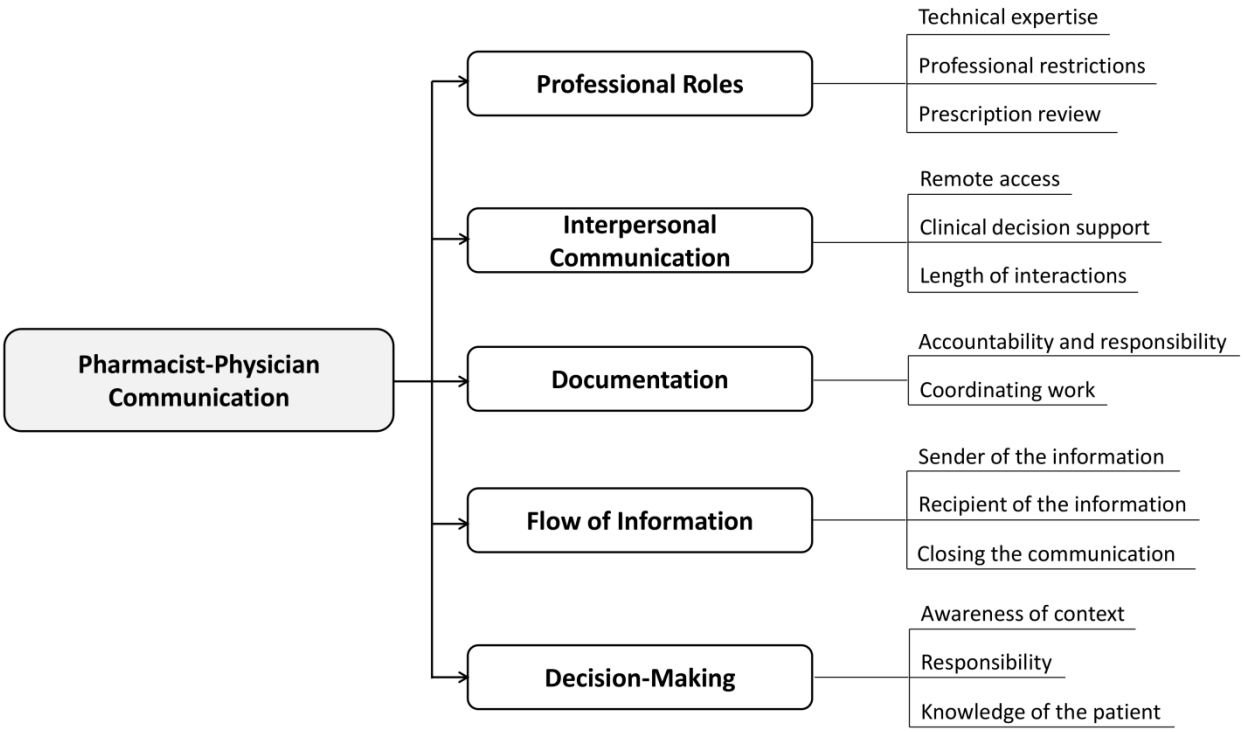


Figure 8.1 – Themes and sub-themes identified in the qualitative analysis of pharmacist-physician communication

8.4.2.1 Professional roles

Technical expertise

The use of a CPOE system within the hospital setting introduced a new 'technical' expert role for the pharmacist. Pharmacists reported that they were contacted by physicians to find out how to complete complex tasks within the system, such as how to prescribe *"infusions"* [P10.B; D8.B] or a titration regimen over a period of days. This was confirmed by the physicians and was observed in both the dispensary and the ward setting. One pharmacist covering a dispensary slot received four phone calls from physicians requesting advice, two of which related to the use of the system, specifically the prescribing of syringe drivers. These requests contributed to *ad hoc* direct and indirect communication between the two professional groups, which would not have existed in paper-based processes.

> *"I suppose that is one of the things that electronic prescribing does introduce, which is the technical aspects of knowing how to use the system. That's what we do often get asked, "How do I do this" which you never would have had obviously if you were just writing it"* [P15.G].

Requests for technical expertise did seem to occur less frequently when practitioners were using systems that provided more complex CDS, such as with standardised order sets in the Critical Care setting. In any case, there was an assumption from the physicians that pharmacists were experts on all functions of the system—most likely because of their association with managing medicines generally. Although there were occasions when pharmacists could explain first-hand how to use elements of the system, there were also times when they would have to *"figure out"* [P4.B] the system so that they could provide

the guidance requested. This was highlighted by the pharmacists taking on a "*nurturing*" [P1.B] role when physicians were new to the hospital and were unfamiliar with the system.

Pharmacists used the assumed technical expert role to their advantage to explain functions of the system that were important for medication-related communication, such as with the review messages at UHBFT. Although it was unclear whether this was conducted in anticipation of any questions they may receive from physicians later on about the use of the message function, pharmacists were certainly aware that the training may not be optimal and that physicians were expected to learn about the system on the job and "*pick it up"* [P5.B] over time.

> *"But I also think you are aware that they're just literally thrown in one minute and you do have to be a bit more* [training]*"* [P1.B].

The pharmacists did not report to dislike the requests for technical expertise, but seemed accepting of the role. It was also suggested by pharmacists that they *"should teach them"* [the physicians] [P2.B] in a more formal role.

> *"[…] I think that's just part of the pharmacists' and doctors' roles changing all the time and electronic prescribing is just another one of these changes […]"* [P12.G].

Although the physicians' role did not change to one of a technical expert to support other staff, they were still expected to gain new technical skills to effectively prescribe for and manage patients within the CPOE system. This was amplified in a hospital where multiple

systems were in use, where "*the difficulty for junior doctors is becoming an expert in a multitude of systems […]"* [D11.G]. Given that hospital CPOE systems vary across the UK, the role of technical expert adopted by pharmacists is likely to continue—at least while physicians continue to move between hospitals during their clinical training.

Professional restrictions

In paper-based prescribing environments, the drug chart is a focal point for physicians, pharmacists and nurses to communicate medication-related information. Working on paper, pharmacists would traditionally annotate (or endorse) prescription orders with information to *"fine tune"* [P9.B] them. Pharmacists reported they had, *"a tendency to scribble all over it* [the prescription] *if it was a paper chart to try and make it right."* [P2.B], such as adding an extra time of day, *"if it was the wrong time, you just crossed it out and put a circle at the correct time"* [P1.B]; annotating *"MR"* [modified-release] [P1.B], or amending the route of administration.

> *"Yes I would have just have gone, oh that should be three times a day, extra circle, or No you don't want that IM* [intramuscular] *you want that sub-cut"* [P14.G].

Within a CPOE system, practitioners are assigned user rights depending on their role and/or level of experience. For example, physicians can generate prescriptions, pharmacists can verify these and nurses can administer the medicines. In view of the restriction placed on professional groups, pharmacists across both sites reported that they were unable to amend and fine tune prescriptions in the same way as they would have done on paper. This led to frustrations among the pharmacists, since without prescribing rights (i.e. as an independent

prescriber), the technology had removed their power to make amendments that they deemed appropriate and importantly ones that they felt confident in performing.
The restriction was reported to, "*lengthen the process a bit*" [P1.B], which was described as a *"faff"* [P14.G] for tasks that they felt capable of completing and increased the need to intervene with the physician compared to paper-prescribing environments.

> *"I think yes we probably are making more interventions than we would if it was a paper chart. Because we'd just write on it rather than making this big thing over it"* [P7.B].

Pharmacists perceived the types of amendments to be low risk, referring to these as *"niggly"* and *"bitty"* [P14.G]. The only exception to this was the ICU setting at GSTFT, where non-prescribing pharmacists could "*make certain amendments and state 'prescriber contacted' for really small amendable things"* [P16.G]. Physicians agreed that pharmacists should be able to amend prescriptions for the benefit of patients, which highlighted a trust and confidence in their ability to perform the task.

> *"[…] And the problem is, it's the patient who suffers at the end of it, so rather than sitting there slipping notes to each other and blaming each other for causing problems, is to actually say, "We will sort out all the low level stuff" and actually sit there and talk to each other about the more important things"* [D7.B].

Even with prescribing rights, pharmacists did not always feel comfortable with making changes to a prescription without informing or discussing with the physician. One

pharmacist described that it felt "*rude to change something*" [P9.B] and as such would document that the change had been made with the use of a P-note (or endorsement note), or discussed it with the physician and then, "*document that discussion*" [D11.G].

Prescription review

It was acknowledged across both sites that using CPOE had eliminated some types of prescribing errors that would ordinarily occur in paper-based prescribing processes, such as those caused by *"illegibility"* [P1.B] of prescriptions, *"spelling mistakes"* [P7.B] and errors of transcribing as a result of *"drug re-writes"* [P4.B]—the need to re-write a drug chart onto another as a result of the limited administration capacity of the chart on paper. Pharmacists and physicians no longer needed to review prescriptions for these errors, which formed part of their routine tasks when working in paper-based process. However, pharmacists reported these had been replaced by a *"completely different error set"* [P16.G] that they would actively and routinely monitor for. For example, GSTFT uses multiple prescribing systems; ICU use a different system (CareVue®) compared to the rest of the hospital (MedChart®) and a separate system was in place to generate all prescriptions for patient discharge (iSoft®). As patients transition from ICU to another ward ("*step down care*") or vice versa ("*step up care*"), medicines need to be transcribed from one system to another. Both pharmacists and physicians were mindful that this introduced a new type of transcribing error at the interfaces of care:

> *"Even within this Trust, there are different systems and it's the interface between the systems that has the most frequent problems. For me I have to deal more and more with*

the step down medications than I did when most of the wards were operated on paper charts." [D11.G]

For the pharmacist, the presence of multiple CPOE systems changed the focus of their initial prescription review, with part of this process now dedicated to checking for transcribing errors. This added to their workload, leaving less time to review and make recommendations to optimise treatment regimens.

"[…] On critical care anyway, I do a lot more medicines optimisation trying to make sure patients are on the right doses. What I found working in other areas, you're doing the step-down check, it's all error checking. Then you're doing the discharge and it's error checking. And then you might get to do some medicines optimisation somewhere in-between that role" [P16.G].

The use of multiple systems also increased the physicians' workload, as they needed to replicate prescriptions for patients at transfer. A physician described the inability for systems to *"talk to each other"* as a *"fundamental safety problem"* [D10.G] when stepping up or down patient care from the ICU.

Errors of transcribing at the transition of care were not raised as a problem at UHBFT, where a single CPOE system was in use. This removed the opportunity for such errors to occur and the need for pharmacists to routinely review for their presence. Nevertheless, in contrast to GSTFT, transcribing issues were raised at UHBFT in relation to the use of paper medical

notes along-side CPOE systems, although arguably this issue would still exist in paper prescribing processes:

> *"I think quite, well not quite often, but sometimes I will look at the clerking and their clerking is perfect, but when you look at PICS, they've then made the mistake when they've gone to put it on PICS"* [P1.B].

The difference between the two sites highlights the importance of interoperability between health information systems—particularly in a single site—and how this can impact on both workload and the type of tasks staff need to perform.

Errors of omission were still reported to occur in both hospitals, possibly driven by the lack of interoperability with community CPOE systems. As such, pharmacists continued to routinely review prescriptions for the presence of these errors. At both sites, pharmacists are able to 'propose' prescriptions for a physician (i.e. of the omitted medicine), to generate the order for their authorisation. This task, now performed routinely as part of the prescription review process with CPOE, would not take place in the paper-based environment owing to the risk that an administration could happen against an unauthorised prescription.

8.4.2.2 Interpersonal Communication

Remote access to information

The ability to access patient and prescribing information remotely via the CPOE system was beneficial for both pharmacists and physicians. Time saving was raised as a particular benefit, since remote working could be used to review more patients in a defined or finite period of time, such as at weekends. Some pharmacists also used remote working to improve their efficiency, such as to *"[…] collate information, look at patients,* [and] *see what needs doing*" [P6.B] prior to attending the ward. Although the ease of access to information has the potential to encourage regular remote working away from clinical environments such as the wards, this was not apparent from the data. On the contrary, pharmacists were aware that working remotely could have a negative impact on interactions with patients, relatives of patients and physicians and so chose to avoid this where possible.

When pharmacists worked in the dispensary, they are remote from patients and staff. In this environment, pharmacists found it harder to make decisions during their clinical review of prescriptions without knowledge of the patient, or being able to speak to the patient about their medicines. At UHBFT, the use of paper medical notes made remote decision-making even harder, since context could not be easily gained from the CPOE system about what decisions had been made during the admission and why.

Physicians reported that pharmacists were visible on the wards and when in contact and communicating, a familiarity between the two professions was observed at UHBFT. Physicians acknowledged the value of having a, *"stable pharmacist on the ward"* [D7.B] and being able to, "*access everything to do with pharmacy through that one person"* [D5.B],

reporting that tasks could be completed in a, *"more timely"* [D6.B] manner when they knew who to talk to. This provides further evidence that the ability to work remotely has not contributed to actual remote working and that interpersonal interaction is important to gain familiarity and build working relationships.

Clinical Decision Support

Many CPOE systems provide CDS to guide practitioners through the various stages of the medication process and to improve clinical decision-making. This can vary in complexity, from being able to provide access to online resources, to more complex active support that can alert practitioners to inappropriate or sub-optimal prescriptions. The CPOE systems in use at UHBFT and GSTFT provide CDS at the point of prescribing. In both sites, the physicians reported that the technology reduced the need to ask as many clinical questions of the pharmacist.

> *"I think from that perspective we probably have to approach the pharmacist less in terms of infusion concentrations and drug doses because most things are integrated into the system. So that makes things easier. I don't know if it makes us make errors less frequently".* [D11.G]

Pharmacists were still observed to receive clinical queries on the wards and in the dispensary via the telephone, particularly relating to the monitoring and review of medicines (e.g. when to take samples to monitor drug concentrations). These interactions were observed to be initiated with familiarity.

The CDS was found to impact on both the frequency and type of interactions that were initiated by the pharmacist to the physician. Although it was acknowledged across both sites that using CPOE had removed some types of prescribing errors, the technology was found to increase the likelihood of certain error types in the prescribing process that would require intervention. Many CPOE systems have the capability to propose order sets when a medicine is selected from a dictionary. This decision support provides the prescribing practitioner with the, "*full set of information required for a prescription"* (NHS England, 2015) to generate a complete prescription, such as the dose, strength, route and frequency. This would ordinarily exist for commonly prescribed medicines such as paracetamol or perhaps those considered high-risk where a deviation from the standard that may put the patient at risk of harm. The CDS is designed to promote accurate prescribing and may also allow prescriptions to be generated in a timelier manner. However, an unintended consequence of these 'default' orders has been highlighted, which is the generation of an inaccurate prescription through the inadvertent acceptance of the proposed order not intended by the prescriber. Physicians at UHBFT quoted that, *"[…] Easily 30–40% of notes* [review messages] *are about doses that are different to the standard PICS dose"* [D5.B]. Both professional groups could recount medicines or types of medicines that most likely contained an error as a result of these order sets, with examples listed such as, "*calcium tablets, like Adcal® or Adcal D3®"* [D3.B], "*statins*" [D4.B] and *"furosemide"* [P4.B]. This type of error was reported as a particular problem on the Admissions wards and so their value in this setting for promoting accuracy was questioned.

"Where the defaults are useful is probably not when you're taking a drug history because you don't want somebody to just input the usual dose range, you want it to be specific for the patient." [P10.B]

Although interventions relating to default orders were not directly observed on the Medical Admissions ward at UHBFT, they were seen to occur on other wards and also by pharmacists in the dispensary. For example, a pharmacist in the dispensary bleeped and subsequently spoke to a physician about a prescription for atorvastatin 10 mg for a patient who usually takes 40 mg according to the drug history on PICS. In this case, the physician confirmed that the dose prescribed was an error and authorised that the pharmacist could change this on their behalf. On questioning, the pharmacist confirmed that 10 mg was the default dose proposed by the system.

Despite awareness that default orders had the potential to provoke certain prescribing errors and impact on workload to rectify these, the benefit of the CDS was also emphasised in helping to reduce higher risk prescribing errors. Physicians were particularly grateful that it helped prevent, "[…] *huge doses or tiny doses of an inappropriate drug"* [D5.B] and reduced the risk of 'slips' in the prescribing process—where their intentions are appropriate but actions are not executed as planned (Reason, 1990; p55)—as a result of external factors such as tiredness. Physicians also found the CDS beneficial in specialist areas of medicine, where, *"defaults are quite useful because they're generally tailored*" [P10.B].

It did not become clear during the study why order sets were inaccurately selected and generated by physicians, although poor access to medication-related information and the

pressure of time were suggested by one pharmacist as potential factors. The former was emphasised by a physician who stated that if the default order did not exist within the CPOE system and the exact dosing regimen for a patient was unknown at the point of prescribing, they would likely prescribe the most common dose anyway.

> *"[…] I guess if I don't know, then I would just pick a common dose and wait for someone to correct me at day time hours…Probably still going to go for 2.5 mg of bisoprolol or 62.5 micrograms of digoxin, which as you say, may well be wrong, but that's probably the same dose I'm going to prescribe with or without the clinical support system."* [D1.B]

Since all elements of a prescription order within a CPOE must be complete for it to be generated—compared to paper prescriptions where an order can be partially completed until further information is available—errors generated as a result of default orders may, in part, also occur as a result of system restrictions.

A second type of error reported to occur as a direct result of CDS was that of 'selection', where the wrong medicine or wrong combination of medicine/formulation or device is selected from a drug dictionary, often because the first on the list is selected. Although these errors did not occur to the same extent as default orders, they still required intervention from the pharmacist to rectify the prescription.

> *"Aspirin dispersible is the first thing that comes up, if they're on EC [enteric coated] because they're on a blister pack, they won't change that, it will be dispersible […]*

and Seretide®, the first thing is Accuhaler because it is alphabetical, so they'll just leave it as Accuhaler" [P5.B].

The errors found to occur as a result of CDS increased the need for pharmacists to intervene and initiate a communication with the physician to rectify the prescription. Overall, it was found to increase interpersonal interactions between the two professions. The inability for pharmacists to be able to amend and tidy up prescriptions within the CPOE system further contributed to the need to intervene directly or indirectly with the physician (section 8.4.2.1: *Professional restrictions*).

Length of interactions

The electronic documentation of requests at UHBFT meant that pharmacists did not need to explain every request directly to the physician, but rather they could direct the physician to a specific patient (or bed number) and ask for the messages to be reviewed accordingly.

"Yes, it's quite good that you can say 'go and see beds 9, 10 and things' but you don't have to be specific about every single thing, you just say 'bed 13 has got four review notes on, go and read them', unless it's something really serious." [P1.B]

This process of communication was only used by pharmacists for requests that they perceived to be low risk and therefore lower priority. Physicians at UHBFT reported that being directed to patients to read requests was beneficial for their time, rather than "*stood over*" [D5.B] whilst the changes were made or the pharmacist needing to wait whilst they wrote the information down. In contrast, at GSTFT where messages could not be assigned

to individual prescription orders within the CPOE system, requests were communicated and discussed with the physician and if not completed straight away, were added to the their task list.

Irrespective of the ability to assign a message to a prescription, pharmacists at both sites adopted a workflow that intentionally reduced the number of times they needed to interact with the physician. They would routinely collate the lower priority tasks to communicate to the physician all at the same time at the end of their shift on the ward. Pharmacists described that they did not want to, *"pester them constantly"* [P2.B] and at UHBFT assigned review messages to avoid having to, *"nag someone about it"* [P3.B], *"follow them"* [P4.B] or avoid *"biting at someone's ear"* [P3.B]. This demonstrated an awareness of how frequent interruptions may impact on the physicians' workflow and potential workload. The increased need for the pharmacist to intervene as a direct result of errors generated through the use of decision support as well as the inability to fine tune prescriptions, may further encourage them to adopt a workflow that minimises interruptions. Pharmacists used analogies such as the, *"school teacher"* [P1.B] and the *"drug police"* [P9.B] to describe how physicians may perceive them—feelings likely intensified by the number of low-risk errors they need to communicate that previously did not exist in paper-based processes.

> *"But I bet from your point of view, you're like 'for god's sake, all the pharmacists can change Adcal, we don't care'. That's what you want to say isn't it [...]"* [P10.B]

8.4.2.3 Documentation

Accountability and responsibility

Pharmacists at UHBFT not only used the review message function to communicate information indirectly to the physician, but also as a formal documentation of their requests and discussions to be held within the patient's clinical record. This was perceived to be beneficial for the accountability of the pharmacist, particularly compared to interventions made solely through, *"word of mouth"* [P2.B] where documentation of the intervention or interaction may not exist at all. It was also described as superior to paper notes used in paper-based prescribing processes, where intervention messages may not be filed in the medical notes or go missing:

> *"You know you have told them but it's also documented somewhere for definite that you told them to review something and they can't say 'oh you didn't tell us about this' so it's kind of good for us from that communication point of view, that we've got a trail to say that we did tell them about something"* [P1.B].

The written (typed up) information in a review message was preferred by the physicians, as it was perceived to reduce the risk of errors through misinterpretation or misremembering information that was relayed verbally.

> *"There are three drugs they need to change by the end of this ward round and I'll probably forget one of them or I can't remember whether she said 15 or 50 [mg]. So the readable information is actually very important"* [D1.B].

The review message communication also meant that physicians did not need to rely on their written task lists or handover sheets transcribed from earlier conversations with the pharmacist, which were reported by one physician as, *"notoriously unreliable"* [D5.B] and often, *"adulterated by other clinicians"* [D5.B]. The documentation of the review messages was therefore also used as a, *"safety net"* [P1.B] by pharmacists to document information or to back-up information relayed verbally to the physician and to provide more detailed information.

Although most transactions within the CPOE system are visible to other users, or can be captured from a large audit database, there is no way of identifying if a member of the prescribing team has read a review message (e.g. such as with a "seen by" or "read by" annotation).

> *"PICS tells you who has changed a prescription as well and deleted one which is good. It would be nice if it perhaps showed if someone's read a review note just so there's some sort of accountability"* [P3.B].

A lack of accountability in this case may impact on the physician's motivation to see the request through and in a timely manner. In addition, since the review message is assigned to a prescription and not directed to a named person or team, physicians reported that this implied a, *"broad team responsibility"* [D2.B]. The inability to assign responsibility for a request means that a single person or team does not need to take, *"ownership of it"* [D2.B], which can lead to an assumption that someone else in the team will pick it up who may be better informed to deal with it. Should a physician choose to amend a prescription or

generate a new prescription, the ability to determine accountability for these changes was perceived as beneficial. However as all actions are either visible or can be captured from a large audit database, it was suggested that maybe, *"people are conscious of 'oh this might come back to me', you know, 'my name is against this forever', so maybe that's why doctors are more scared to action our notes* [messages] *perhaps"* [P2.B]. The lack of accountability to identify when messages have been read and by whom, in combination with no assigned responsibility for dealing with the requests, means that messages can be ignored without repercussion. This was perceived to impact on the overall effectiveness of the electronic communication, leading to either no action or lack of a timely action.

Coordinating work

The documentation of review messages facilitated communication between the pharmacists at UHBFT and was used as a means of, *"handing over to other people"* [P2.B] to coordinate care. First, as the messages are accessible to all users of the CPOE system, pharmacists were reassured that any outstanding requests would be followed up by another pharmacist where necessary (e.g. if the patient is moved to a different ward). The review message icon on screen made requests visible and accessible, without which *"follow-up would be harder"* [P1.B]. Second, the review message helped pharmacists identify which patients had been reviewed, facilitating prioritisation of work and avoiding duplication, which would be *"time consuming"* [P5.B]. Pharmacists were observed to read messages as part of their routine workflow on PICS, hovering over or clicking on any existing review message icons to inform their tasks. On occasion, pharmacists were also seen to sign these off if the request had been actioned or dealt with, which removed the icon from the screen and the prompt to follow-up. This suggests that the documentation of review messages is used for more than

simply communicating information to physicians, but also to display activities and actions to coordinate care amongst the pharmacy team.

Pharmacists at UHBFT also reported to document information using the 'pharmacy message' function within the CPOE system. Here, they would write down the confirmed medication history of the patient (as there is currently no dedicated function within the system to do so) and document any medication-related, *"interventions for audit purposes"* [P5.B]. Despite an element of duplication, this was also perceived as beneficial to coordinate work between the pharmacists. Not only were all the ward pharmacists observed to look at the pharmacy messages to inform their review of a patients' prescription, but they were also used by pharmacists in the dispensary to verify prescriptions that needed to be supplied. The pharmacy messages (as the name would suggest) were not perceived to be a pharmacist-physician communications and although some pharmacists *"taught"* [P5.B] physicians to look at it in an attempt to coordinate care, this practice was not consistent, which was confirmed by the physicians. The fact that technicians can also write in the pharmacy messages to coordinate work with the pharmacist may contribute to its hidden use, as *"there could be a potential for error"* [P2.B]. If the information was used by a physician before had been verified by a pharmacist. With this in mind, it is not surprising that the need for a dedicated "*tab"* [P10.B] to document the medication history was raised as a potential benefit both professions.

8.4.2.4 Flow of information

Pharmacist as sender of information

Pharmacists modified both the modality and timing of communication based on their perception of the urgency of the request and therefore the associated risk to the patient. Pharmacists consistently reported that direct and immediate communication would be used to communicate with the physician for urgent cases and that multiple forms of communication would be used to ensure the information was exchanged in a timely manner to ensure quick action.

> *"If it's urgent, we would speak to a doctor. If they're not there, you would phone, you would email and make sure they get a response back to whatever. You would not go home that day without making sure... you know you've communicated with the doctor about something urgent"* [P9.B].

This was confirmed by the physicians, who agreed that direct communication was always used and reiterated that an extra step was needed for these types of communication, such as, "*old fashioned bleeping and talking to each other"* [D4.B]. Remote working, such as when covering the dispensary, made contacting the physician more difficult at times and was observed to be time consuming for the pharmacist when bleeps were not answered and alternative means of contact needed to be sought. This process was not perceived to be any different to how pharmacists would work in paper prescribing environments, except that identifying who to contact was easier via the CPOE system. Initiating direct communication on the wards was far easier in comparison, although there were times when this was observed to be harder, such as in the afternoon when junior physicians were in

teaching and when physicians need to move between wards to see patients who were outliers. All these tasks were made more difficult for new rotational pharmacists who were unfamiliar with the setting and teams.

Pharmacists at UHBFT reported that the review message would never be used as a single modality of communication for urgent requests, but that information may still be documented in the review message for accountability and to avoid misinterpretation of the request at the point of prescribing (see 8.4.2.3, *Accountability and responsibility*):

> *"Yeah, but you could say 'I've put a review note on that', like you'd contact them straight away. Because over the phone it might get confusing, they might get the wrong dose over the phone or something, whereas if it's written down, it's more solid"* [P4.B].

Avoiding the review message for urgent requests may emphasise the pharmacists' lack of confidence in this modality of communication to alert physicians to requests that require immediate attention. Confidence in the effectiveness of system alerts was also highlighted by the pharmacists' approach to inform the physician about omitted medicines, which may or may not be regarded as urgent depending on the medicine. The pharmacists at UHBFT would not only propose the medicine for the physician, which would create a "flashing" alert tab on a patient's profile, but would also issue a repeat communication by assigning a review message to the first available prescription on a patient's prescription profile to direct the physician to look at the 'proposed' flashing medicines tab. The repeat communication suggests that the pharmacists were aware of the potential for alerts to be overlooked and as

such adopted a, *"workaround"* [P10.B] to reinforce their request, since there was no other means of communicating information about a medicine that does not exist on a patient's profile.

Pharmacists at both sites adopted the same workflow for communicating non-urgent requests with the physician. The details of each request would be written down as a personal prompt to, *"pick it all up at the end of the day"* [P14.G] with the physician and would be communicated at the same time at the end of their shift on the ward (see 8.4.2.2, *Length of interactions*). Although it was not clear from the focus group data how these were documented as reminders for the pharmacist to follow-up, observation at UHBFT showed that this was always conducted on paper. At UHBFT, the requests were also documented as a review message, which as discussed, served as an additional prompt for the pharmacist to help coordinate care, document accountability and provide more detailed information for clarity.

Since the action of non-urgent requests in both sites was dependent on the verbal handover and prompt from the pharmacist, the amendments to prescriptions likely occurred at similar times—towards the end of the pharmacists shift on a ward when these were all communicated. This may suggest that the electronic communication of requests has no impact on the time to action. The only difference being that the pharmacists at UHBFT have documented the request in the interim period.

Physicians as the recipients of information

The CPOE system at UHBFT does not actively alert physicians when a review message is assigned by a pharmacist, rather it passively highlights the presence of a message with an icon on a patient's prescription. The physicians' receipt of a message is influenced by their awareness of the presence of a message on a patient's profile, which was found to be dependent on: 1) being prompted by the pharmacist; 2) the visibility of the message on the screen; and, 3) the physician's perception of what the messages would request based on previous experience of the content of these.

First and as discussed above, pharmacists at UHBFT prompt physicians to read messages on screen to ensure the information is communicated effectively. Since physicians are aware that this will largely take place during the day and, that pharmacists will inform them directly of urgent cases, there is little motivation to read messages without direction to do so. One physician admitted that when the pharmacist was not around on a particular day, they, *"don't review the drugs properly or it happens sporadically*" [D5.B]. This was reported to be particularly true at weekends when pharmacists were not ward-based to follow-up requests directly with the physician.

> *"So any review notes you put on, sort of late on a Friday are not conveyed to a doctor and will get missed until Monday. If there's a patient you have to see, if you're worried about them you might look at it [the review message], but at the same time since it's probably going to be "Please change this Adcal prescription", you may well*

not do, because I'm interested in the fact that this patient's very septic. I'm not bothered about their simvastatin or whatever" [D8.B].

"I generally haven't come across a review note [message] that cannot wait a weekend. I mean they're generally relating to medications which it's just not a disaster if you have missed two days" [D1.B].

At UHBFT, the presence of a review message is identified by a small grey 'R' icon on an individual prescription order on a patient's profile (see 5.1.2). Pharmacists emphasised that the review messages may not be highly visible and that this is likely to contribute to the overall effectiveness of the communication being received. Both professionals used words such as *"subtle"* [D8.B] and *"little"* [D8, P3.B] to describe the icon, indicative that the visibility is not perceived as optimal. The use of the letter 'R' in the design was also questioned since physicians may not be aware that this refers to 'Review'.

"I'm just thinking about the R, if it said 'review' on it, maybe they'd be more inclined to actually look into it, because R could mean anything. They don't necessarily know it means you need to review this medication" [P7.B].

The visibility of the review message was compared to the, *"sticky note"* [P10.B] that would be placed on a drug chart in a paper-based prescribing environment—described as being more *"glaringly obvious"* [P6.B] for the physician. The disadvantage of these notes was also raised though, with there being a tendency for the notes to physically, *"fall off"* [D5.B], as well as the inability to audit the process to, *"measure it appropriately"* [D7.B].

Finally, the inability to ascertain the priority of a request was raised as an issue, since all review message icons are visibly the same. Pharmacists use the review message to communicate and document information on a range of themes—some simply providing supporting information and others requesting an action such as an amendment to a dosing regimen (see section 6.3.3.11). Irrespective of the topic of the request, the physician is required to click onto each message icon to read the information, determine a priority and act accordingly. Although suggestions were made about really urgent messages being designed to have a clear priority, this was considered in the context of other interruptive *"flashing"* [D9.B, D7.B] alerts within the CPOE system and how these already had an impact on workload and workflow. Considering that pharmacists use the review message function to facilitate handover with others (see 8.4.2.3, *Coordinate work*), document information and discussions for accountability (see 8.4.2.3, *Accountability and responsibility*) and only communicate non-urgent requests, it is understandable that with repeated exposure to messages over time and no means of ascertaining a priority, the physicians' response to the messages wanes.

> *"The more messages there are, the less likely they are to be actioned and if the first one you click on is rubbish, how likely is it that you're going to go down the list?"* [D7.B]

Pharmacists acknowledged that numerous review messages assigned to a patient's profile could have a negative impact on overall effectiveness of the function of communication, giving reason for the physician to, "*glaze over them*" [P5.B], or causing them to feel overwhelmed.

Closing the communication

Pharmacists and physicians at both study sites emphasised the importance of face-to-face communication and that a, *"two-way system"* [D9.B] was more beneficial for conversation and discussion. Pharmacists at GSTFT were more inclined to handover medication-related requests directly, as there was no means of communicating a written message and assigning this directly to a prescription. The non-urgent requests could be rectified there and then or potentially noted down by the physician for attention at a later date. This approach increased the opportunity for discussion and the length of the interaction (see 8.4.2.2, *Length of interactions*). Importantly, the pharmacist (as the sender of the information) also gained immediate feedback on their request, allowing the communication, in the most part, to be closed. In contrast, at UHBFT, the directing of the physician to review named patients or bed numbers was found to impact on the pharmacist in two ways. First, as the sender of the information, the pharmacist was left in a position of having to wait for their request to be actioned and monitor when this has been completed. Second, where no action was perceived to have occurred on follow-up, the pharmacist would feel ignored and *"deflated"* as a result [P1.B].

> *"But yeah, it's a bit deflating at times, going back to what, it's just like 'day 3, still not done it', so you feel like you're in a way wasting your time, because you're not seeing as many of the new patients because you're reminding them again about the ten review notes that are still not actioned"* [P1.B].

> *"You know, it takes such a long time sometimes to do a review note. It does. It took ages getting this drug history and at the end of it you leave these reviews. When nothing is done about it, you're like 'What was the point of me wasting my time doing this when you're not going to do anything about it"* [P7.B].

The uncertainty as to whether requests have been considered is further exaggerated by the physicians' poor use of the 'sign-off' function within the system. Sign-off is intended to be used by physicians to remove the 'R' icon from a prescription when the request has been dealt with or the information considered (see 5.1.2). Pharmacists reported that, *"only a few doctors"* [P5.B] actually signed-off messages and found that they would sometimes be signed-off, *"to get rid of it* [from the screen]*"* [P4.B], but not do anything about it. This was certainly observed on a General Medicine ward, with one pharmacist suggesting that the poor use of the sign-off function may reflect the physicians' knowledge of how it should be used (i.e. as a means to acknowledge the request and close the communication). However, the poor use of the sign-off function may also be intentional, as a result of a lack of knowledge about the system as a clinical patient record (see 8.4.2.1, *Technical expertise*; 8.4.2.3, *Accountability and responsibility*). Concern was raised by some physicians about the availability of the documented messages if they were signed-off, with one physician describing the sign-off as messages ,*"falling off"* [D2.B] the system and potentially getting lost.

For the physician as the recipient of the information, the review message function does not enable two-way communication, as either a free-text or a tick box to state the outcome of the request. As such, they are unable to provide feedback or a rationale back to the

pharmacist and close the communication. Physicians reported this as difficult, acknowledging (in the uni-professional focus group) that this can appear that the information has been ignored and that they, *"can't be bothered to process"* [D4.B] the request. Physicians reported a desire to provide feedback and since this was not possible within the system, adopted a workaround to enable this.

> *"I will quite often, when I sign-off a drug and I think there might be some question as to why I have changed or signed-off, I will put a P note saying 'as per pharmacist review notes'... because then when the next clinician comes in they won't necessarily immediately know why and they won't know how to get to the old review notes and if there's a P note there it might be more obvious to them." [D5.B]*

8.4.2.5 Decision-making

Awareness of context

Pharmacists and physicians reported difficulties gathering information relating to the context of prescribing decisions that had already taken place. The CPOE systems in both sites were described as effective in providing the information needed to determine 'what' had changed over time and was described as a, *"massive improvement"* [D1.B] compared to paper drug charts, which were difficult because they only last a finite period of time (i.e. 2–4 weeks). However, the reasons 'why' often prompted a need to intervene with the physician for clarification, either directly or with adding a review message to the prescription.

"I think that's why we end up putting a lot more review notes on as well. Because I know I have chased a lot of doctors about when inhalers have been switched and I know now that obviously on one ward I covered that yeah, they have probably done this intentionally, but because there's nothing written down, you still have to go and ask and leave a review note. So I think that kind of wastes everyone's time a little bit as well. So I think the documentation in the note, if that was clear it would be useful." [P8.B]

On reading the review messages from pharmacists, physicians at UHBFT reported their difficulty in determining whether prescriptions for a patient were generated with intention, or whether errors were actually present. This uncertainty was reported to stem from poor or no documentation of medication-related changes in the medical notes, which had the potential to lead to uninformed changes to be made to prescriptions and also contribute to delays in actioning requests.

"By the time they get to the ward they, it does cross your mind that maybe this prescribing error was on purpose... maybe it was changed deliberately in CDU [Clinical Decision Unit] *in some way and you know you look through the notes and you've got no real way of telling, so I'll change it on the assumption that it was mis-prescribed for whatever reason, maybe just because the PICS default or something else […]"* [D8.B].

Although some physicians reported that they documented information in the medical notes, it was also acknowledged that this was not consistent practice. The use of paper medical

notes alongside CPOE, described as a, *"half-way position"* [D5.B], was believed to be a contributing factor to this, since the notes were not present in the workflow when interacting with the CPOE system. As further evidence of this, the documentation of medication-related changes was not raised as an issue by the pharmacists working within the ICU setting at GSTFT where both the CPOE and electronic notes are available within the same system. Here, the prescribing pharmacists working within the ICU setting explained that any changes they made would ordinarily be backed up with a discussion—a routine confirmed to be the case by a physician— with exception of *"obvious"* or *"straightforward"* amendments to prescriptions that may just be documented in the electronic notes.

In an attempt to provide context, some (but not all) physicians and prescribing pharmacists at UHBFT adopted a workaround to communicate a rationale for their prescription changes, making them visible to others with using the P-note previously described.

> *"[…] I occasionally use P-notes myself if I pause something, so if I pause something I put a P-note saying why I've paused it because otherwise two weeks later it's still paused and no one knows why. But they've got to scroll through the notes if it's not clear."* [D8.B]

This particular workaround has a clear disadvantage when there is a need to communicate a rationale relating to a prescription that has been stopped and so is not present on a patient's prescription profile to assign a P-note. Interestingly the workaround to provide the information was consistently reported to occur within the CPOE environment and not in

the medical notes separate to the system. This may suggest a preference for all the information to be held within a single place—within the CPOE system.

It was unclear whether pharmacists and physicians faced the same difficulties in the paper prescribing environment. Given that fewer communications may be needed to determine 'what' has changed over time, the overall frequency of communications may be lower or no different. However, the strong desire for a, *"timeline"* [D2.B] of medication-related changes and facility for, *"highlighting anything that's happened to that drug in the history"* [D5.B] emphasises the importance of an audit trail to access appropriate and relevant information and the potential for this to have a positive impact on workload.

Responsibility

For more junior physicians, the act of generating a prescription is often under the direction of a more senior member of the team. Physicians described that prescribing at the request of another physician was hard at times, as they would need to generate prescriptions that they were not necessarily comfortable with. The confidence to amend these prescriptions was suggested by pharmacists as a potential reason why requests were not actioned—unprompted by the physicians and raised in the uni-professional focus group.

> *"[…] especially if they've been on a ward round with a consultant. They're a bit scared of, they're scared of changing any of their prescriptions"* [P1.B].

The responsibility for a prescription that originated under the direction of someone else, whether new or amended, was a concern for the more junior physicians. The role of the decision-maker and the person generating the actual prescription initiated discussion about the need for review messages to be directed at a named person more appropriate to deal with the request (i.e. the decision-maker or consultant with overriding responsibility). However, this was also contested since a facility to direct a message to a particular person would mean that the request is no longer visible for everyone interacting with PICS to see, which may further reduce the likelihood that the message will be seen and a timely action taken. A function in the CPOE system to highlight when prescriptions were recommended by someone else was also suggested, such as a, "*third party action*".

> *"I wish there was a third party action. I often find that consultants or registrars prescribe drugs that I'm not comfortable prescribing. I'm logged into PICS or they'll say 'Prescribe that' and I'm logged in and I'm like 'OK...'* [nervously]*" [D5.B].*

Physicians reported the use of the P-note as a workaround to document where the direction for a prescription originated from, such as with, "*prescribed at the request of…*" [D2.B] annotated. As previously discussed, the physician would also provide an annotation when changes had been made at the request of the pharmacist: (see section 8.4.2.4: *Closing the communication*). It was unclear whether this was conducted to remove responsibility from the prescriber back to the decision-maker or the pharmacist, or to facilitate the direction of any queries to the appropriate person.

Knowledge of the patient

Knowledge of the patient was an important factor for physicians when making prescribing decisions at the request of a pharmacist. Decision-making was found to be particularly affected during on-call hours, such as overnight or at weekends, where knowledge of all the patients potentially under a physician's care was not possible. First, in this situation, physicians were wary about amending prescriptions that were generated by another team, rationalising that it was not their, *"duty"* [D2.B] to respond to requests and these were best left to someone who, "*might know something more about the patient*" [D3.B].

> *"I mean there are occasions when, usually ward cover situations, where you're just sort of covering an acute out-of-hour episode and prescriptions relating to their sort of chronic medications, I tend to leave them. I don't feel that I am in a position to say 'why is this amlodipine 5 mg rather than 10* [mg] *when he has been taking 10'. There might be a very good reason for it. I don't feel I'm in a position to know the patient to sign-off that note* [review message] *in which case I'll leave it". [D1.B]*

Second, taking responsibility for these requests was difficult given the lack of context of medication-related decisions documented within the CPOE system and medical notes, which may be considered even more important for informing physicians about patients not known to them. The pressures of on-call, *"fire-fighting the sick ones"* [D3.B], explained why review messages were not prioritised by physicians, except in situations where the acute presentation of a patient may be medication-related. The fact that review messages are only used by pharmacists to communicate non-urgent requests [see section 8.4.2.4, *Pharmacist as sender of information*] and that there is no way of identifying the priority of a

message [see section 8.4.2.4, *Physicians as the recipient of information*], are both likely to contribute to the reduced response of physicians during on-call hours at UHBFT.

8.5 Discussion

Understanding the unintended and unanticipated effects of new technology allows those individuals and teams working in the delivery of care to be in a unique position—one of power to plan for the change and adapt accordingly. The unanticipated effects become anticipated, which can promote a more proactive approach to patient safety. In this study, the use of CPOE in the hospital environment was found to impact on the communication load of pharmacists, which in turn had a direct impact on the workload of the physician. The effectiveness of communications sent electronically (asynchronously) via the CPOE system were found to be largely affected by their design. An asynchronous approach to communication was also found to have a potential impact on interpersonal interactions and coordinated care.

8.5.1 Communication load

From the physicians' perspective, the demand for technical guidance with the CPOE system increased interpersonal communication, but the number of clinical queries were perceived to fall. From the pharmacists' perspective, the need to communicate with the physician had increased owing to the loss of power to amend prescriptions in an electronic format; the occurrence of prescribing errors as a result of interactions with CDS (e.g. the unintended selection of default order sets) and interoperable systems; and the difficulty ascertaining context for prescribing decisions (see Figure 8.2).

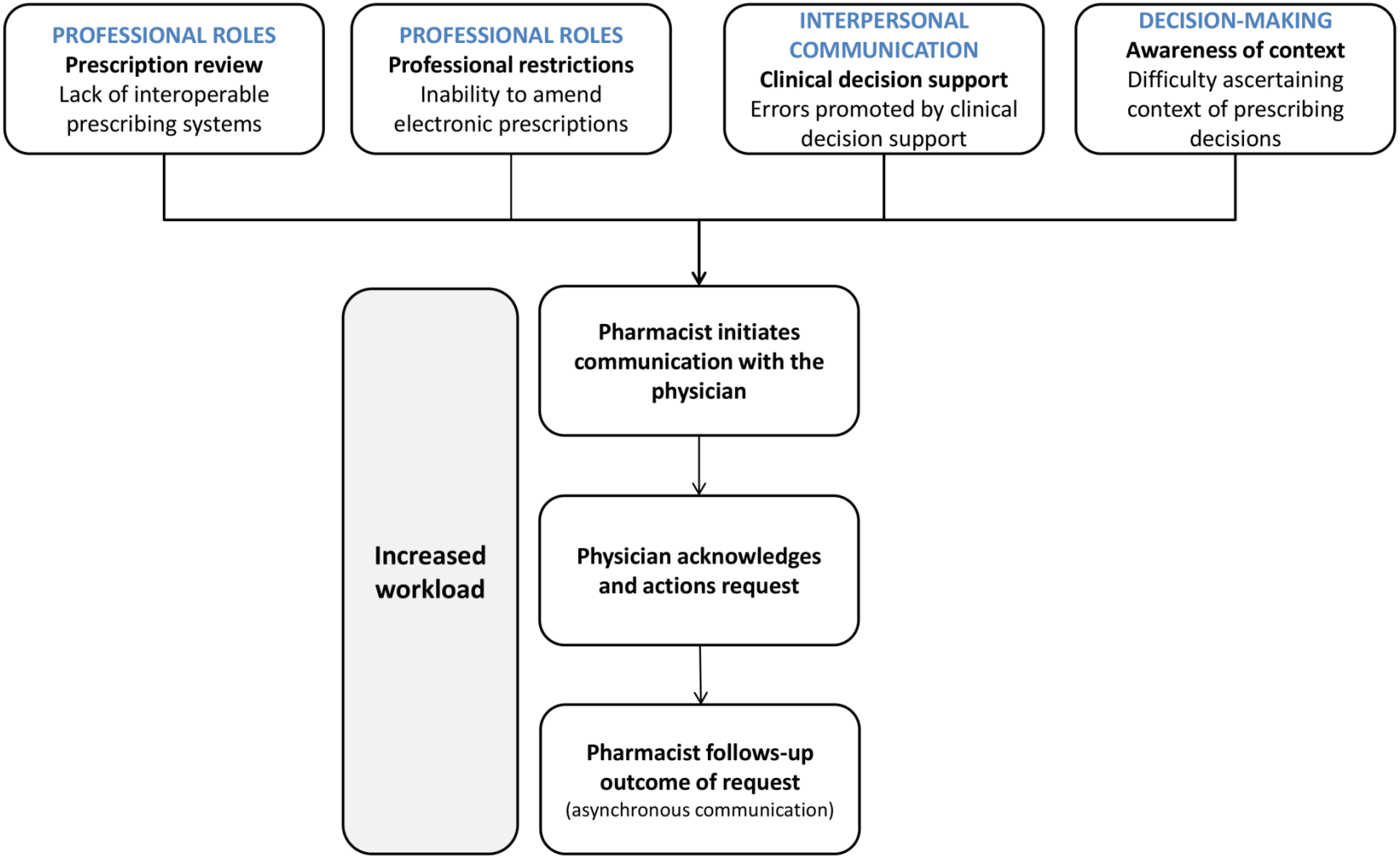


Figure 8.2 – Impact of CPOE on pharmacists' communication load

In the hospital setting, physicians were found to rely on pharmacists to provide technical expertise when they needed assistance with medication-related tasks within the CPOE system. This was found to continue in an environment with a well-established CPOE system in use and increased when physicians were new to the hospital and unfamiliar with the technology. Pharmacists associated the increased workload from technical queries to gaps in the physicians' knowledge of the system and the time allocated to training. The informal role of technical expert assumed by the physician and subsequently adopted by the pharmacist has previously been described by McMullen *et al* (2015), who found that pharmacists became, "*informal trainers*" of systems post-implementation of CPOE and spent time showing physicians how to efficiently use the system (McMullen *et al.*, 2015). Of course, the demands for technical expertise are likely to be greater immediately after the implementation of a system but in contrast to the findings in this study, McMullen *et al* (2015) also found that the support demanded from physicians, *"diminished with time"* and experience. This reduction in requests may be a reflection of the depth of training provided to practitioners pre-implementation compared to the on-going training provided long-term (i.e. during the induction of new staff).

Training has been identified as a key consideration for successful implementation and on-going use of CPOE (Cresswell *et al.*, 2013b; Joint Commission, 2014) and although a range of training methods are used by hospitals to deliver this to staff (Brown *et al.*, 2017), interprofessional training has not been identified as an approach. It is part of the hospital pharmacists' role to ensure that prescribers are, "*supported in their everyday activities by readily-accessible information and guidance"* (Royal Pharmaceutical Society, 2014; Standard 5.1, p 15). The continued demand for informal interprofessional education from the

pharmacists suggests that physicians find it beneficial and that pharmacists are generally well-placed and accessible to perform the task. This *ad hoc* guidance is likely to fall over a weekend though, since ward-based pharmacy services are still rare in hospitals in England (Office of the Chief Pharmaceutical Officer, 2016). A study to investigate socio-technical incidents occurring at UHBFT found that these occurred more frequently on a Sunday compared to the rest of the week ($p<0.013$) (Redwood *et al.*, 2011), which may reflect the lack of informal training and support available at this time. Informed by their own experience of the system and the types of queries received on a regular basis, pharmacists may be able to provide a greater depth of training, but further research is required to determine if this would be beneficial and how this should be formally embedded into organisations.

Insufficient training can lead to sub-optimal use of systems—the use of the technology in a way that is not intended (i.e. workarounds) or underuse of system functions— which may increase the risk of error (Baysari *et al.*, 2012; Mozaffar *et al.*, 2017; Redwood *et al.*, 2011). This was perceived to be a contributing factor for the sub-optimal use of some system functions at UHBFT, particularly those relating to the coordination of tasks. Physicians' inadequate use of the 'sign-off' function to indicate that a review message had been acknowledged, led to uncertainty for the pharmacist about whether a communication had been received. As such, requests communicated via the review message often remained on their task list to follow-up, which added to their workload. Sub-optimal use was not also raised by the physicians, which may reflect a lack of knowledge or poor awareness of how and why other professional groups interact with the system, the expectations of others and how to work with the system to coordinate work. Cresswell *et al* (2013) recommend that

"*the most effective training is tailored to the individual roles of users, without being too restrictive as this can undermine understanding of how the whole system functions*". Although this may be true in ensuring routine tasks can be completed in the system to deliver everyday care, it may not consider the use of the system in relation to interprofessional communication or how best to use system functions to coordinate care. Such knowledge of the system may only really be gained through interprofessional training, so that practitioners can develop skills together in the context of CPOE and, *"learn with, from and about each other to improve collaboration and the quality of care"* (Atkins, 2002). Knowledge of how others use the system may have the potential to reduce informal requests for guidance and reduce workload generated as a result of poor coordination of tasks.

Pharmacists were found to assess the urgency of their requests for the physician and adjust their communication so that it was appropriate to the situation. Significant requests that required prompt action were dealt with immediately and directly with the physician. However, for non-urgent requests, pharmacists favoured a workflow that minimised interruptions for the physician. They were reported (and were observed) to collate non-urgent requests and communicate all these to the physician at the end of the day (or their shift on the ward). The analysis of a situation and *"appropriate obtrusiveness"* (Schmidt, 2002) approach was perceived to be no different to how they would have worked in paper-based environments. This was found to be in contrast to some studies that show hospital work to be more task driven and dependent on interruptive communication to that these can be completed in a timely manner (Coiera & Tombs, 1998; Edwards *et al.*, 2009; Popovici *et al.*, 2015). Based on this, pharmacists placed an emphasis on facilitating the workflow of

the physician, rather than removing tasks from their own workload and working memory. At UHBFT, with the capability to communicate requests asynchronously and electronically, pharmacists also adopted a modality of communication that could minimise the length of time of the interruption. Interruptions that are unrelated to the task being completed can lead to multi-tasking (Edwards *et al.*, 2009), impact on working memory (Coiera & Tombs, 1998; Parker & Coiera, 2000) and shorten overall time spent on tasks (Mark *et al.*, 2008; Westbrook *et al.*, 2010). The review message function enabled the pharmacist to communicate information indirectly—independent of the location and activity of the physician (Wu *et al.*, 2013)—and removed the need for a detailed verbal hand-over of the request through directing physicians to review named patients or bed numbers at a time that was convenient for them. In addition to this being beneficial for the physicians' time and workflow, the written requests were preferred by the physicians as they did not need to rely on their working memory (Parker & Coiera, 2000), and thus reducing the risk of information being misremembered or misinterpreted. Although the desire to minimise the length of interruptions was conducted with the best intentions, it does have the potential to reduce opportunities for informal interaction (Harrison *et al.*, 2007) and formal discussion, both of which are essential to gain context and to promote collaborative working practice.

The non-interruptive workflow routinely adopted by pharmacists suggests that they are socially aware and sensitive to the activities or tasks being carried out by physicians, which may encourage them to engage at a more appropriate time to minimise interruptions (Bardram & Hansen, 2010; Heath *et al.*, 2002). Developing a social awareness is easier when working in close proximity to other healthcare professionals (such as on the ward). The CPOE system enables remote access to information and often the capability for multiple

practitioners to access a single patient record at any one time. It has been known for some time that this has the unintended potential to encourage remote working, causing practitioners to be spatially distributed from one another, which can reduce interprofessional interactions (Barber *et al.*, 2007; Barber *et al.*, 2006; Campbell *et al.*, 2006; Dykstra, 2002; Harrison *et al.*, 2007) and have a negative impact on social awareness. In this study, the capability to access information remotely via the CPOE system did not appear to affect the proximity of practice of the pharmacist and physician. On the contrary, pharmacists and physicians emphasised the importance of working together in the same space and were fully aware that CPOE had the potential to encourage remote working, which they reported to actively avoid. The presence of the pharmacist was also found to be important for prompting the review of prescriptions, which may otherwise not be prioritised (Brown *et al.*, 2014). Proximity of practice to the patient and their relatives was also stressed, as this was considered essential to gather information and gain context. As such, in the context of CPOE, pharmacists maintained an awareness of the activities of the physicians and this was perceived to be no different to paper-based processes.

CPOE systems can enforce or reinforce professional standards and boundaries (Niazkhani *et al.*, 2008), for example, by restricting actions according to profession or grade. The restrictions placed on pharmacists to amend or "fine tune" prescriptions was found to increase the communication load for the pharmacist, compared to the freedom they had on paper to make minor adjustments to treatment regimens. The pharmacists' written endorsements on paper drug charts have been found to "*subtly influence medical prescribing*"(Liu *et al.*, 2014) and are conducted with the intention to benefit patient care, either for the safety of the prescription or to align treatment to the patient's usual regimen

so that the hospital admission reflects their medicine-taking behaviour at home (e.g. adjustment of times or days or doses). Previously made known to the physician by a different coloured pen or an allocated space on the chart, the pharmacist would traditionally make amendments on behalf of the physician for low risk and low significance errors that they felt competent to action, which reduced the need to intervene with the physician. In the context of CPOE, it was not always possible for pharmacists to amend the electronic prescriptions and even prescribing pharmacists were wary to do so without informing the physician, possibly because the amendment is less apparent on screen than it would have been on paper (Niazkhani *et al.*, 2008). This restriction increased the workload for pharmacists, as there was now a need to communicate—at UHBFT there was also the added need to follow-up that the task had been actioned since the pharmacist would not necessarily wait for these to be completed at the time of handover. The low significance of these fine tuning requests is likely to further encourage a non-interruptive approach to the communication, with wanting to avoid distracting the physician for menial tasks. The demand for these tasks to be completed over time may also have an impact on the pharmacists' professional identity—including "*the perception of themselves as professionals"* (Morrow *et al.*, 2011)—with a feeling that it may promote a belief that they spend time tidying up prescriptions as the "*drug police*", rather than as experts in medicines. Although the frustrations of these errors may seem small in one or two settings, they are likely being faced by pharmacists in all hospitals settings that utilise CPOE systems. The change in communication load highlights the importance for systems to be flexible and designed to account for existing work processes (i.e. in a paper-based environment). However, the very fact that systems have not allowed pharmacists to make changes may cast doubt on whether pharmacists were previously acting outside the scope of their

practice when working in paper-based processes. Standards clearly state that pharmacists should "*intervene with prescribers*" (Royal Pharmaceutical Society, 2014; Section 6.2, p16), to ensure the safe and effective use of medicines. Further clarification may be required from professional bodies as to the extent to which prescription orders in a CPOE system can be amended by non-prescribing pharmacists and how prescribing pharmacists should approach these in the hospital setting. It is also important that physicians are engaged in this process and consulted on when setting these standards. Finally, where amendments are possible by the pharmacist, these should be clearly visible to other practitioners (e.g. in colour). Amendments made to paper drug charts have been found to influence prescribing (Liu *et al.*, 2014) and the potential for learning to be gained from this day-to-day feedback should not be overlooked. It is important that physicians see the types of fine tuning and low risk amendments that are being made to prescriptions so that they can adjust their practice to avoid these in the future (Ferguson *et al.,* 2017).

The use of CPOE in the hospital setting has been found to reduce the likelihood of a medication error occurring by almost half (Radley *et al.*, 2013) and reduce the rate of preventable adverse drug events (Nuckols *et al.*, 2014). The use of integrated CDS software is considered to be the main reason for these benefits (Kaushal R, 2003). Although pharmacists and physicians in this study acknowledged that CPOE could remove some medication errors, they were also aware of errors relating to the use of the technology, particularly CDS and could name common medicines associated with these. A systematic review conducted to investigate the types and causes of prescribing errors within CPOE systems found that CDS in the form of default orders (sometimes referred to as auto-complete or auto-populated orders) and drop-down menus can lead to prescribing errors

through the acceptance or selection of an incorrect order (Brown *et al.*, 2017; Singh *et al.*, 2009). The occurrence of these errors at the study sites was found to add to the communication load of the pharmacist and therefore the workload for the physician; those relating to default orders were perceived to contribute the most. The use of default orders to *"nudge"* practitioners along an appropriate course, such as generic versus brand prescribing, have been shown to be effective at instilling and maintaining a required standard of prescribing (Malhotra *et al.*, 2016). However, nudging towards a regimen that has the potential to vary depending on the patient and/or the indication for treatment may be less beneficial in practice. The fact that default orders were perceived to contribute to a proportion of communications (and tasks for the physician) suggests that the decision support is leading to a sub-optimal use. Access to information and time were suggested as potential contributing factors for the occurrence of the errors. A lack of information may cause the physician to consciously accept the inaccurate order until the information is known. It was unclear from the data how frequently this may occur in practice, but it is likely that a lack of interoperability with electronic patient records (e.g. medical notes) and with records from other settings (i.e. the community) increases the likelihood of these, since the information is not available to the physician in a single location to aid their decision-making. In the presence of CPOE, the physician may be inclined to accept a default order and generate a prescription without knowledge that it is correct, compared to not prescribing a medicine until all the details are confirmed in a paper-based system. Physicians may be encouraged to continue with system defaults to remove the task of prescribing from their workload and may feel reassured that an error would be identified by a pharmacist before it is administered to the patient (Dornan *et al.*, 2009). In addition, unlike on paper where a prescription can be partly generated with the unknown details left

blank—acting as a visual clue to return to the chart when the information is known—this is not possible within a CPOE system (Niazkhani *et al.*, 2009).

A lack of time may result in physicians completing tasks quickly so that they can move on to the next. The acceptance of incorrect orders when information about the patient's history is known, may suggest that physicians are not only interacting with the system quickly, but also without conscious thinking. "*Consciousness is tuned to picking up departures from intention*" (Mandler, 1975, cited in Reason, 1990; p 10), therefore, prescriptions that are generated not entirely as intended (e.g. incorrect dose) may occur as a result of automatic unconscious thinking, where less attention is paid to the detail of the order and with little or no effort applied to the review—so called "*System* 1" thinking (Kahneman, 2011; p 20-21). Kahneman (2011) describes how some activities can become "*automatic through prolonged practice"* (Kahneman, 2011; p 22) and that System 1 thinking has learned associations. Default orders are often configured for frequently prescribed medicines (e.g. *"statins"*). Over time, physicians will become familiar with the most common dosing regimens for medicines and may also gain knowledge of these through the frequent and regular use of the system. Taking this into account, orders may be accepted as correct through association (i.e. of the most common regimen), without conscious thinking to check that the regimen is consistent with the patient's needs—omitting an *"attentional check*" (Reason, 1990; p 61) to ensure the populated prescription on screen matches the patient's medication history when generating the prescription. The use of default orders in systems may have the unintended effect of encouraging this System 1 thinking when generating a prescription, leading to an over-reliance on the CPOE system to make decisions and active failures (as slips) to occur (Reason, 1990; p 57). The use or design of default order sets in systems requires further

investigation to minimise the risk of active failures occurring (van der Sijs *et al.*, 2006), particularly for those regimens that have the potential to vary according to the patient and indication for treatment. Although some of the errors may seem insignificant because they are expected and likely to be caught, there is a risk that 'default fatigue' could lead to these escalating and becoming significant if they are not proactively managed (Furniss *et al.*, 2011).

Interoperability of patient records is important to enable the seamless delivery of care. Timely access to information to inform decision-making has clear socio-economic benefits for organisations (EHR IMPACT, 2009; Lederman & Parkes, 2005; Walker *et al.*, 2005). It is not surprising then that interoperability is a key recommendation in the plan to digitise the NHS in England (National Information Board, 2014; Wachter, 2016). A lack of interoperability between inpatient systems at GSTFT was found to impact on the role of the pharmacist, their communication load and the demands of the physician. As well as the obvious duplication of tasks conducted by physicians when moving patients in or out of the ICU setting, pharmacists were required to dedicate time to review prescriptions for the presence of transcribing errors and intervene where necessary. This was reported to take them away from other professional tasks such as the optimisation of treatment regimens. Pharmacists and physicians were aware of the risks associated with multiple CPOE systems and described the lack of interoperability as a "*fundamental safety problem"*. The use of paper medical notes alongside CPOE systems was also found to be problematic, largely associated with the lack of information potentially driving the default orders previously described. Interoperability of electronic patient records and CPOE systems within the same

hospital and across care settings is likely to reduce the communication load of pharmacists and the subsequent workload of physicians to amend prescriptions.

The CPOE systems at the study sites were found to facilitate the easy capture of information relating to 'what' treatments had changed for patients over time (e.g. during an admission), but the reasons 'why' remained largely unknown, since systems did not provide the capability to document a rationale and for this to be accessed retrospectively. Gaining context of prescribing decisions was found to be problematic for both pharmacists and physicians and this led to uncertainty on the pharmacists' part, with the need to communicate with the physician to clarify the status of prescriptions. On receipt of a request from the pharmacist, physicians reported that they would often struggle to make decisions, since a lack of documentation and poor access to information made it difficult to determine whether the prescription was as intended, or whether there was an unintended discrepancy. This has the potential to lead to, "second order errors", where a correct prescription is amended and an error is generated as a result. The reduced interaction with using asynchronous communication may also further affect physician decision-making. Requests were also reported to be left for someone else to deal with who may be more familiar with the patient in question. The use of electronic patient records has previously been found to impact on physicians' clinical reasoning, because, although systems can provide a lot of patient data, it is not always easy to gain enough knowledge of the patient to inform decision-making (Elrouby and Tully 2017; Varpio *et al.*, 2015a). In this study, physicians expressed a need for a function within the CPOE system to provide a, *"timeline"* of events, so that prescriptions changes over time could be viewed to ascertain the patient's treatment journey. This is consistent with a study that found clinicians want to, *"build the*

patient story" (Varpio *et al.*, 2015b) when delivering care and reported that the electronic patient records fragmented information, which made the story difficult and time consuming to construct. The ability to retrieve a retrospective account of what has happened is important for physicians (Reddy *et al.*, 2001) and this study suggests that it is also important for the pharmacist. Bardram and Hansen (2010) argue that, "*workplace awareness depends on collecting, processing, distributing, displaying and sharing information about the constantly changing work context"*. At UHBFT, pharmacists and physicians reported the use of a workaround within the CPOE system to display their actions relating to prescribing decisions, so to share these with other healthcare professionals. This in turn enables other practitioners to collect the information to inform decision-making. Although workarounds are often seen as discrepant, they can be conducted to achieve organisational goals and can highlight areas where CPOE systems function sub-optimally (Cresswell *et al.*, 2016). This workaround shows that pharmacists and physicians need to share and collect information to coordinate work, which in turn will facilitate decision-making. Given the pressured environment of the hospital setting, it is important that staff involved with the medication process can gather sequential information quickly and accurately when interacting with electronic patient records. A function within CPOE systems to facilitate this would be beneficial, detailing what changes have been made, why and by whom. This would help avoid uncertainty at the point of prescription review. As previously discussed, it is also important that this information is available in a single location (i.e. the CPOE system).

8.5.2 Effectiveness of the communication

Physicians and pharmacists across both study sites emphasised the importance of direct communication and that this should not be replaced by asynchronous modalities. This was particularly true for requests that were urgent, or perceived to be urgent by the pharmacist. Close proximity of practice—found to be unaffected by the use of CPOE at both sites—was considered important to increase the opportunity for informal interactions.

The effectiveness of the review message communications—where messages are received in a timely manner by a physician who can take action accordingly—was found to be influenced by a number of factors relating to the documentation of the request and the flow of information. Figure 8.3 summarises the factors found to impact on the receiving and action of requests sent via the CPOE system.

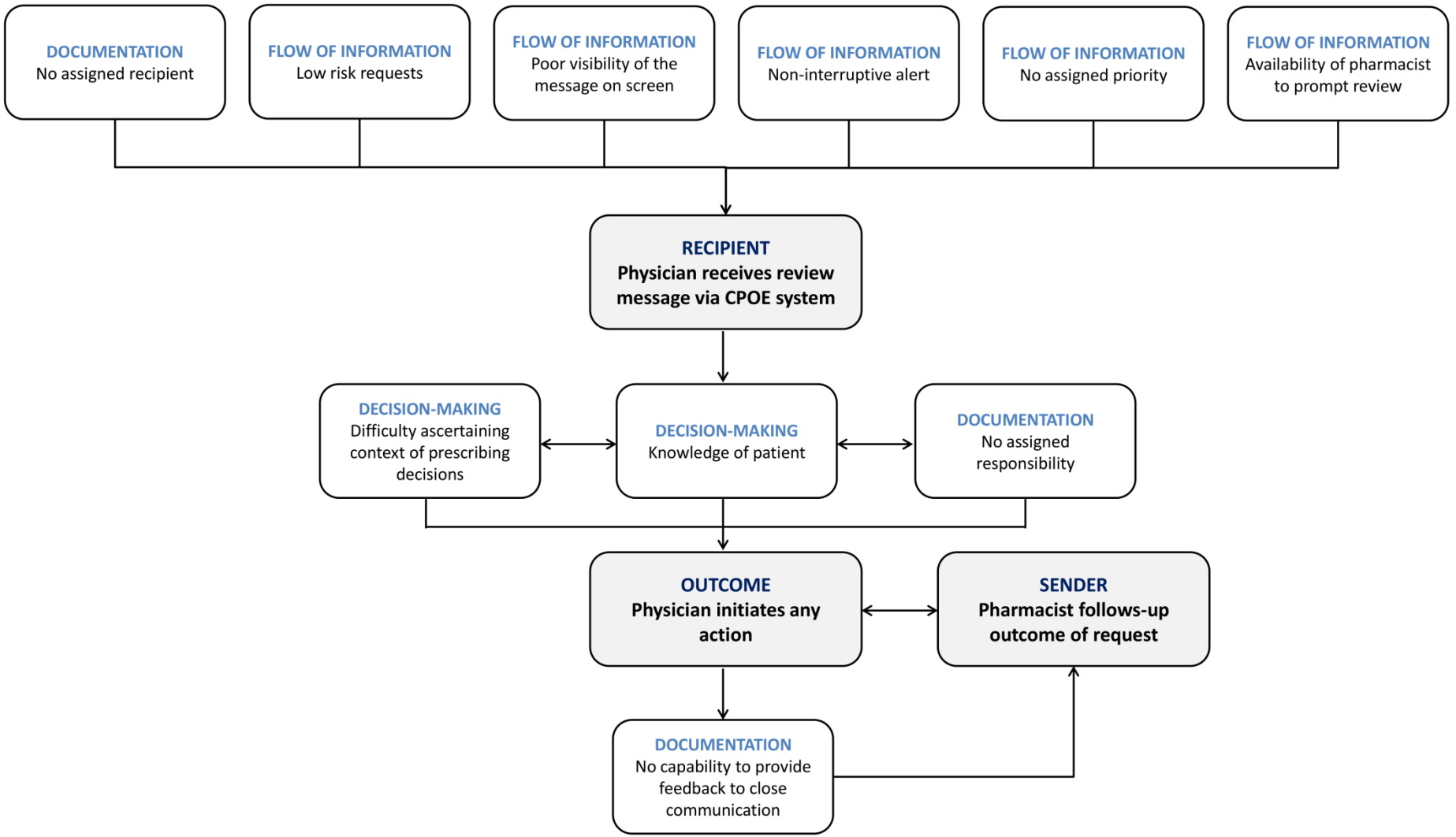


Figure 8.3 – Factors found to impact on the receiving and action of review messages sent via the CPOE system

The use of electronic messages was found to have clear benefits for the physician, such as reduced interruptions to their workflow—important for reducing the risk of clinical and procedural errors (Edwards *et al.*, 2009; Popovici *et al.*, 2015; Westbrook *et al.*, 2010). However, it has the disadvantage of reducing the length of interpersonal interactions, which is important for discussion to gain context, to develop professional relationships and to promote collaborative working (Liu *et al.*, 2010; McDonough, 2001). It was suggested by participants that when asynchronous methods are adopted, such as the review message, *"two-way"* communication would be beneficial, since feedback was considered important. A uni-directional message means that physicians are unable to provide a rationale for their decision-making. Should a request be ignored for valid reasons, clinical or otherwise, this cannot be explained to the pharmacist and may appear that their input has been ignored or not considered. This has the potential to impact on the professional relationship, as well as the lack of feedback contributing to the pharmacists' workload with the need to follow-up requests with the physician. Incorporating bi-directional communication into CPOE systems could enhance the effective flow of information, which in turn can help manage workload and enhance coordinated care (Ighani *et al.*, 2010; Reddy *et al.*, 2005).

Human factor principles applicable to the design of alerts in CPOE systems have been described to include: visibility; confusability with other system messages or alerts; and the ability to determine a priority (Phansalkar *et al.*, 2010). The effectiveness of the review message at UHBFT as a form of communication was reported to be affected by these factors. First, the visibility of the message on screen was perceived to be sub-optimal since the size and colour did not distinguish it from other types of messages. Using an image or word that is associated with the profession is likely to prompt more immediate recognition,

as well as an enhanced awareness of the work of the pharmacist. Second, there is no facility to assign a priority (or severity) to requests, so those that are perceived to be more significant are not highlighted as such. In the present system, the approach taken by pharmacists to use direct communication for amendments they perceive to need immediate attention is entirely appropriate. Although 'priority' is recommended by Phansalkar *et al* (2010) as a design feature for alerts and it was discussed as a possible improvement to the system, there is a potential risk of encouraging the use of asynchronous communication methods for urgent requests. On the other hand, it could increase the chance of messages being reviewed out of hours when the pharmacist is not ward-based and serving as a visible prompt for the physician to follow-up medication-related reviews. It is important to be aware that the addition of a design feature to assign a priority may also have the unintended effect of causing habitual behaviours (Baysari *et al.*, 2017; Phansalkar *et al.*, 2010), or *"alert fatigue"* (Khalifa & Zabani, 2016; van der Sijs *et al.*, 2006) where the physicians' response to the alerts falls over time.

The application of electronic messages in CPOE systems has the benefit of allowing certain activities to be recorded in the patients' electronic record. As previously discussed, this was found to be beneficial for facilitating the coordination of work between pharmacists—providing a platform through which requests could be followed-up—and reduced the risk of information being misremembered or misinterpreted by the physician. Unlike requests that are discussed or handed over verbally, the assignment of a message also generates a clinical documentation that is visible and that can be retrieved at a later date. This was perceived to be useful for accountability, since it provided evidence that the task had been communicated by the pharmacist, which in turn could be used for organisational audit and

monitoring. However, the design of the review message at UHBFT was not found to be effective in assigning a responsibility to the task, as the message was not directed to a team or person. This was considered to impact on the effectiveness of the communication, since without being forced to take ownership, the messages may be more likely to be overlooked. This, combined with a poor awareness of context to easily build a *"patient story"* (Varpio *et al.*, 2015b), is likely to impact on the physicians prioritisation of review messages and may encourage requests to be left for others to deal with who have more knowledge of the patient. Pharmacists recommended that 'read by' requests might be useful so that accountability could be determined. The use of *"technovigilance"* (Dixon-Woods *et al.*, 2013) in this way, to use the audit capability of the CPOE system to monitor the physicians' transactions within a system and determine accountability, may have the unintended effect of causing physicians to completely avoid entering the message field; further reducing the effectiveness of the communication.

8.5.3 Strengths and limitations

This qualitative study was designed to ensure rigour during the investigation and analysis of data and to optimise the reliability of the findings. However, as for any research, there are limitations that need to be addressed. The focus groups were conducted in only two hospital sites in England. Although the salient themes I have discussed emerged in both settings and provide evidence of data saturation, the findings should be interpreted in the context of the settings investigated and may not be transferable to all hospitals.

This study was designed with consideration of my own experience and assumptions as a pharmacist working in hospital and with CPOE systems. Focus groups were facilitated by a second independent researcher and a proportion of the data were independently coded. The observational research was also conducted by multiple investigators. These steps were taken to reduce the risk of methodological or confirmation bias during the investigation and to gain a range of perspectives. There are many methods that can be applied to assess reliability of qualitative research and there are differences in opinion as to how this should be best approached or approached at all (Cook, 2012). As such, the approach taken here may be open to criticism and perceived as a limitation.

Non-participant observation was conducted at UHBFT of hospital pharmacists performing their routine clinical work on the wards and in the dispensary. This method was adopted to provide further data to explain the themes that emerged in the analysis of the focus group data at the site. Physicians were not observed directly, but were observed when interacting with the pharmacist, both directly and indirectly. As for the focus groups, data saturation was achieved as no new topics or themes emerged and so further observation beyond the 20 hours conducted was not scheduled.

8.5.4 Conclusions

The use of CPOE was found to increase the communication load of pharmacists in the hospital sites investigated, which also had a direct impact on the physicians' workload. This increase in workload inevitably reduces the time pharmacists can spend on other tasks, such as spending time with patients to discuss their medication and reviewing prescriptions to optimise treatment regimens. For the physician, the increase in workload may also lead to

multi-tasking, with an increased risk of clinical or procedural errors occurring. In view of this, it is important that factors such as system restrictions, system-related errors, interoperability and context of prescribing decisions are considered in the design of systems and how organisations choose to configure these for local use.

The use of CPOE increased interactions between the professionals as a result of technical guidance sought from the physician. Although these interactions are beneficial for building working relationships, the reliance on pharmacists as technical experts highlight that training may not be sufficient. This can result in sub-optimal use of systems, with the potential to increase the risk of errors. Organisations needs to ensure that adequate training is provided for staff so that they can complete transactions within systems that are relevant to their role and can communicate and coordinate care in the context of the technology.

The capability to communicate information asynchronously and specific to a prescription order in the CPOE environment was perceived to be beneficial to facilitate a non-interruptive workflow. The messages helped reduce the length of interruptions for the physician, allowed for the documentation of requests for accountability and, reduced the risk of misremembering or misinterpreting information communicated verbally. However, the message function investigated could be improved with the addition of bi-directional communication. This has the potential to increase professional interactions, which can promote the sharing of information to coordinate work, facilitate awareness of context and promote collaborative working. The function would also benefit pharmacists' workload, as they receive timely feedback relating to their requests, potentially reducing the need to

follow-up the status of these with the physician. This is something organisations should consider when selecting a CPOE system with asynchronous communication as an option.

Chapter 9 DISCUSSION

In this chapter, I assimilate the findings from the systematic review of the literature and the quantitative and qualitative analysis of pharmacist-physician communications. Through a process of triangulation, I aim to present an integrated view of the findings to explain how the use of CPOE and CDS technologies in the hospital setting have an impact on pharmacist-physician communication.

9.1 Background to the research question

The implementation of CPOE technology has been shown to have many benefits for patients and healthcare professionals, in particular a reduction in some types of medication errors and associated harms. Evidence also suggests that systems have the potential to cause unintended and unanticipated consequences, such as on workflow and the quality of communication between staff. A systematic review of the literature (Thomas & Coleman, 2012) found that few studies had investigated the impact of this technology on communication between the pharmacist and physician in the hospital setting—a relationship integral to achieving and maintaining safe and effective medication use.

The aim of this research was to understand how the use of CPOE and CDS technology may impact on pharmacist-physician communication. The objectives of the research outlined in Chapter 1, were to:

1. Determine the effectiveness of uni-directional electronic communications sent via a CPOE system in a large acute hospital and identify factors that may influence this;
2. Ascertain the perceptions of pharmacists and physicians of their interprofessional communication in the context of the technology; and,
3. Observe pharmacists routine clinical work and their professional interactions in the context of the technology.

9.2 Triangulation of findings and recommendations

The findings from the systematic review, quantitative analysis and qualitative analysis will be discussed in three themes: 1) interpersonal interactions; 2) communication load; and, 3) effectiveness of communication.

9.2.1 Interpersonal interactions

It was not clear from the review of the literature how CPOE and CDS would impact on interpersonal communication (section 2.3.2.5). Although it was noted that it had the potential to reduce opportunities for interaction because of the increased use of the computer to perform tasks (Ash *et al.*, 2004); there was also evidence to suggest that it could increase interactions owing to the need to coordinate tasks, which was not possible via the computer (Niazkhani *et al.*, 2010). In this study there was no evidence to suggest that access to CPOE—with or without a means of electronic communication—affected the

presence of the pharmacist on the wards. Pharmacists and physicians were mindful that CPOE systems could encourage remote working and only chose to work away from the wards where it was felt necessary for the delivery of the service (e.g. weekends).

Data analysed between January 2009 and December 2014 showed a year-on-year increase in the pharmacists' use of the review message function to communicate with physicians at UHBFT (section 6.2.1). In isolation, this finding could suggest an increasing preference to use asynchronous methods of communication, confirming that the technology has the potential to reduce interpersonal interactions. However, qualitative data captured from both pharmacists and physicians suggest that the increased use is much more strategic than simply an over reliance on the modality compared to more direct methods. First, pharmacists were found to favour a non-interruptive workflow in both hospital study sites, primarily to facilitate the work of the physician. They routinely collected tasks that they perceived to be of relative low-risk and would communicate these directly with the physicians towards the end of their shift on the ward. Though this was not perceived to be any different as to how they would have worked in paper-based processes, the added capability to assign a review message meant that pharmacists could also reduce the length of disruption to the physician's workflow—relying on the review message to provide the detail needed for the physician to review the request and take action at a time convenient. The preference to avoid distracting the physician is beneficial to workflow and can reduce the risk of procedural and clinical errors occurring (Popovici *et al.*, 2015; Westbrook *et al.*, 2010). Second, pharmacists and physicians were clear that the technology was not relied upon to communicate requests relating to high-risk errors and that these were routinely communicated directly and immediately with physicians so that any problems could be

rectified early. Although a small proportion of messages at UHBFT (3.8%, see 6.2.3.3 and Appendix 7) were found to relate to one of the 80 high-risk errors identified in Chapter 4 (Thomas *et al.*, 2013), the communication of these via the CPOE system was to ensure clinical documentation for accountability and audit, rather than as the sole means of transferring the information. The process of duplicating the communication as a review message provides an effective safety net—avoiding the need for the physician to rely on memory or written task lists to recall verbal information. This shows that pharmacists not only routinely assess the potential risks of prescription orders on patient safety, but also that they evaluate the effectiveness of communication methods to select an appropriate modality based on this—choosing interpersonal interaction when tasks needed to be completed quickly. Finally, the documentation of messages was also used as an effective way of helping to coordinate work between members of the pharmacy team. In contrast to the findings from the systemic review that found staff did not rely on systems to coordinate tasks (section 2.3.2.2), pharmacists used various messaging function within the CPOE system to do just this. The presence of the message icon provided an effective prompt to follow-up on tasks, facilitate handover and effectively monitor the stages of the medication process. The same coordination of work was not apparent among the physicians, possibly because they were unaware that messages could be accessed retrospectively.

Direct communication is important for developing effective working relationships. Although CPOE did not discourage direct communication, the ability to communicate with electronic messages assigned to prescriptions had the potential to reduce the length of interactions between staff, since the detail of requests no longer needed to be verbally handed over. It is important that pharmacists and physicians remain mindful of the potential for systems to

reduce interpersonal interaction, particularly as systems increase in complexity and become integrated with other Electronic Patient Records (EPRs), making access to information easier and remote working more feasible. This has implications for educators working in undergraduate health education, as there is a responsibility to familiarise students with the technology they will work with and the associated processes they will work in upon qualifying. Incorporating the use of EPRs (such as CPOE) with an interprofessional approach would enable students to acquire the non-technical skills to work alongside the technology and each other to develop effective communication techniques. Training relating to the use of the technology should also continue to be interprofessional at postgraduate level so that staff understand the role of others in the context of the medication process and the technology. This mutual understanding is essential for achieving integration in multidisciplinary teams and successful engagement (Atkins, 2002; Keller *et al.*, 2013; Luetsch & Rowett, 2015).

9.2.2 Communication load

Over a 12-month period, pharmacists at UHBFT assigned 36,245 review messages to prescriptions in the CPOE system, 34,506 of which were analysed for the quantitative study. The process of writing a message, physician review (and potential action) and pharmacist follow-up takes time and the population of multiple messages on a patient's prescription profile was found to have a negative impact on the overall effectiveness of the message function. Although a proportion of the message load has been rationalised above in relation to documentation and coordination of tasks (9.3.1: *Interpersonal interactions*), factors have

been identified throughout the research which have a direct impact on the communication load of the pharmacist.

Just under half of all messages were found to relate to the reconciliation process, a larger proportion of which identified discrepancies in the dose and frequency of medicines compared to patient's pre-admission regimens. Given that the coding of messages was based on the pharmacist clearly stating a comparison to pre-admission regimens, this is likely to underestimate the true number of discrepancies. This finding may highlight the difficulties faced by healthcare professionals in accessing relevant and accurate patient information at transitions of care, particularly in ascertaining an up-to-date and complete medication history. The number of dose/frequency discrepancies compared to unintentional omissions of treatment—more commonly seen in this process—may also highlight that information at transitions of care is incomplete. Not only does this present an on-going risk for patients, but it also adds to the daily workload of pharmacists and physicians in the delivery of care—time that could be spent with patients in working to optimise treatment regimens. The implementation of interoperable EPRs across sectors of care and at transitions of care (e.g. in the same hospital) is already a priority for the NHS (National Information Board, 2014; Wachter, 2016) and this finding highlights this as a priority for patient safety.

Pharmacists reported that a proportion of review messages they sent intended to clarify the status of prescriptions. This may account for the 10.5% of messages assigned to prescriptions providing 'Supporting Information' about a patient's usual regimen, but that did not make a direct request for a change to be made in case the prescription was actually

generated as intended. This communication load was found to occur largely as a result of not being able to gather information about why prescription changes had been made during a patient's admission, since the prescribing decisions and associated rationale were not well documented. This process was considered easier in a paper-based process, where the information is less fragmented in comparison (Cresswell *et al.*, 2014; Varpio *et al.*, 2015a). A capability for both physicians and pharmacists to document medication-related changes within the CPOE systems and the rationale for these, could provide the context needed for healthcare professionals to *"build a patient story"* (Varpio *et al.*, 2015b), necessary to inform their decision-making. This information can inform the ongoing care of the patient in helping to improve communication at transitions of care.

The restrictions systems can place on professional groups means that pharmacists cannot amend (or fine tune) electronic prescriptions in the same way as they would have done on paper charts. This was considered another contributing factor for their increased communication load. An example of this is the annotation of *"MR"* (modified-release) on paper, when the standard-release formulation is incorrectly prescribed. Messages requesting the physician 'Changes the formulation to a modified-release form, to be consistent with pre-admission' occurred 697 times over the 12-month period. Similarly, requests to 'Change the formulation from a modified-release to standard-release form, to be consistent with pre-admission' occurred 93 times. These two examples alone accounted for 2.3% of all the messages and provide evidence of how this loss in power to make changes can impact on workload. The routine practice of annotating paper drug charts can reduce the need to intervene with the physician and ensures that patients can adhere to their usual medication routine soon after admission to hospital. In the paper-based setting,

pharmacists are also reassured that their amendments are clearly visible to the multidisciplinary team. However, it is important to note that this practice is not outlined in professional standards for hospital pharmacists in the UK (Royal Pharmaceutical Society, 2014). To align the practice on paper to that on the computer, pharmacists would need to be able to continue to make changes to electronic prescriptions, but professional standards may be necessary to ensure this is documented to ensure consistent and safe practice. In addition, to reflect the visibility of changes in paper processes for audit and feedback purposes (Ferguson *et al*., 2017), systems would also need to be designed so that any changes can be easily identified on screen by the multidisciplinary team.

In the review of the literature (section 2.3.2.5), it was not entirely clear how the use of CDS would impact on the frequency of communications. One study found that it could decrease the number of interruptions for the physician (Niazkhani *et al.*, 2010), largely because the system can force adherence to a formulary of medicines available in the hospital. There was also a perception that CDS would replace the pharmacists' need to intervene owing to its ability to prevent certain prescribing errors and provide guidance for physicians (Aarts *et al.*, 2007). Consistent with these findings, CDS was appreciated by users since it helped to prevent slips in the prescribing process and therefore remove the need for some clinical interventions by the pharmacist. It was also found to reduce communications directed from the physician to the pharmacist as a result of the guidance received from the system. However, the qualitative research also highlighted some negative effects of CDS on the accuracy of patients' prescriptions and therefore on the communication requirements of pharmacists.

Default order sets—"*a full set if information to complete a prescription proposed by CDS"* (NHS England, 2015)—were identified as a particular problem, since accepting these led to inaccurate prescriptions being generated inadvertently. Pharmacists and physicians highlighted specific medicines where this was considered to be a problem, namely *"Adcal D3®"*, *"furosemide"* and *"simvastatin"*. Simvastatin and furosemide were found to be amongst the top ten medicines to have a message assigned that was directly associated with the prescription. For simvastatin, a third of messages related to a discrepancy compared to the patient's usual pre-admission regimen, almost half for furosemide and a third for Adcal D3®. For these three medicines alone, the communications accounted for 2% of all the messages. This correlates with the suggestion that these specific medicines often had dosing errors and that a proportion of these were likely as a result of default order sets. It may also explain why the majority of discrepancies relating to the reconciliation process were dose/frequency errors, in contrast to errors of omission more commonly reported in the literature (Quélennec *et al.*, 2013; Urban *et al.*, 2014). The Francis Inquiry Report (2013)—an independent inquiry into care provided by a large NHS hospital in England—recommended that, *"systems should be designed to include prompts and defaults where these will contribute to safe and effective care and to accurate recording of information on first entry*" (Francis, 2013). The use of default orders should be reviewed owing to their propensity to cause error and impact on patient safety. The use of defaults are most beneficial for medicine regimens that do not vary between patients (such as complex infusions based on the patient's weight in the ICU setting), or where elements of the regimen do not vary between patients (e.g. frequency, time and route for simvastatin). Partial population of prescription orders would ensure that the components of the prescription that should not vary are correct and that the physician applies conscious

thinking to add the missing (variable) information for each patient—an approach that may reduce the risk of developing habitual routines of accepting alerts (Baysari *et al.*, 2017; Phansalkar *et al.*, 2010). The CDS could also be configured to include minimum and maximum ranges to reduce the risk of harm from input errors. An alternative approach could be to implement an alert to encourage the physician to double check the prescription against the intended or required regimen. However, over time the effect of these may diminish as it becomes one of many alerts that physicians need to deal with (van der Sijs *et al.*, 2008b).

A second error reported to occur as a result of CPOE and CDS were those of selection. The quantitative study found that these were mainly as a result of incorrect drug/formulations and drug/device combinations in the drug dictionary, rather than the inadvertent selection of a look-a-like drug name. For example, when aspirin "*dispersible*" is prescribed instead of the "*EC* [enteric coated]" formulation taken by the patient; or when the wrong device (e.g. for inhaled therapy) is prescribed for a patient— just two examples of error that accounted for 1.4% of all the messages. Combination errors such as this have previously been found likely to occur in CPOE systems (Gerrett *et al.*, 2009). To minimise the risk of selection errors occurring, drug dictionaries could be designed to contain only one variable (i.e. name of medicine), rather than multiple components of the information needed, such as including the device or formulation. Forcing prescribers to consciously select the additional elements of the prescription in a separate field would encourage a second check against the intended or required prescription, which should minimise the risk of error. Although selection errors of the 'wrong drug' were not found to be prevalent in the database, the true number may be much higher. These errors are likely to pose a higher risk to patient safety and so are

more likely to be rectified directly and immediately with the physician. Tall man lettering—where sections of a word are capitalised to highlight distinct differences with look-alike words—could be considered for specific names of medicines that look-alike on screen, or sound-alike when acting on a verbal request (Gerrett *et al.*, 2009), that are frequently observed to cause error. Although systems can be optimised to reduce the risk of error inducing interactions, such as with Tall man lettering and avoiding default regimens, it is also important that all healthcare professionals are aware of the potential for systems to cause error. The use of CPOE and CDS should be integrated into undergraduate health education to ensure the future workforce is digitally competent and aware of the unintended consequences of systems—necessary to optimise and improve the use of technology in healthcare to benefit patient care (Wachter, 2016).

Finally, a large proportion (9.2%) of the messages assigned to prescriptions was made to inform the physician that a medicine had been omitted. Qualitative data suggested that a review message would routinely be assigned to the top medicine on the patient's profile list to inform the physician and request (where applicable) to pay attention to prescriptions proposed on behalf of the physician within the CPOE system. This was confirmed in the quantitative analysis, with nearly half of all these messages assigned to medicines starting with letters A to C. The review message was used as a workaround to provide information that was unrelated to the prescription and occasionally to direct the physician to review another function within the system. Workarounds have the potential to create situations prone to error, but can also be a sign of resourcefulness and highlight functions of the technology that require modification (Cresswell *et al.*, 2016; Koppel *et al.*, 2005). This particular workaround may highlight a problem with the visibility of proposed medicines

within the system at UHBFT and the need for a dedicated function so that pharmacists can communicate contextual information solely related to omissions of treatment. The ability to flag information to the physician about an omitted medicine or a specific function dedicated to omitted medicines, would reduce the number of unrelated messages populating a patient's prescription profile, which may reduce the risk of message fatigue, particularly to those assigned to the top medicine on a patient's prescription profile.

9.2.3 Effectiveness of the communication

The process of communication is dependent on the modality of communication, any *"noise"* in the process that may affect the message being received (e.g. number of messages) and the facility to provide feedback (see Figure 1.1) (Lunenburg, 2010). In this study, an effective communication via the CPOE system was one where information is received by the intended recipient (physician) in a timely manner (within 24 hours) to achieve a response. The expected response is not necessarily one to act to adhere to the request of the pharmacist, as this may not always be appropriate—rather it is an action to consider the information and review the prescription order in question.

9.2.3.1 Receipt of the information

The effectiveness of electronic communication via the CPOE system is firstly dependent on the information being received. The review of the literature identified that the ergonomics of electronic communications is important to ensure accessibility is optimised (section 2.3.2.4). This was raised as a factor at UHBFT since the visibility of messages was perceived to be sub-optimal, which could affect accessibility. This could be improved by their

presence being distinguishable from other types of messages in colour and size and icons designed to relate to the profession initiating the communication (Phansalkar *et al.*, 2010). A second factor considered important for the initial receipt of messages was the number of message icons on a patient's prescription profile. It was evident from the focus group data that multiple messages on a patient's prescription profile could have a negative impact on the effectiveness of the message function and lead to a sense of being over-alerted and *"burdened"*. Nearly a quarter of all the messages assigned to prescriptions provided 'Supporting Information' and a proportion of these requested that the physician monitors specific parameters—information that is largely provided by the CDS when prescriptions are first generated. From the recipient's perspective, this increases the number of message icons on a patient's prescription profile that provide information not deemed necessary, with the unintended effect of encouraging habitual behaviour to avoid paying attention to all messages in the longer-term. To optimise the effectiveness of electronic communication, message functions should be reserved for making explicit requests and recommendations and alternative functions used to provide supporting information. Pharmacists should also consider their modality of communication for patients that require multiple interventions—discussing these directly with the physician and rectifying these collaboratively to ensure desirable outcomes are achieved and in a timely manner. This would prevent the physician from feeling overwhelmed by multiple requests at the point of prescribing, promote collaboration and help reduce the risk of message fatigue. These changes in practice would need to be supported with training and may also require a change to local protocols. A function to assign a priority to messages was also suggested as a way of identifying the messages on screen that needed attention (section 8.5.2). Although this may be useful to help physicians prioritise work when out-of-hours, it may encourage pharmacists to use the

system for higher-risk communications, with the unintended effect of reducing interpersonal interaction and increasing the risk that these requests may be overlooked.

The receipt of messages was also perceived to be influenced by whether a responsibility was assigned to deal with the request (i.e. to a named person or team) or for responsibility to be identified based on who has received the information. One of the recommendations for safer clinician communication in the context of EPRs is for the status of the communication to be visible, such as *"sent, delivered, opened, acknowledged"* (Office of the National Coordinator for Health Information Technology, 2014). In this study, it was not possible to determine from the data the number of messages that were received and read by physicians, since there is no function to capture this within the system (i.e. read by receipts). Without a function to identify this, responsibility cannot be assigned to an individual (i.e. who has opened the message) to acknowledge the information and take action. Implementing the capability to monitor the status of communications could encourage interaction between the sender and the recipient of the information. In addition, the data captured from this capability can provide the organisation with a greater insight into the effectiveness of communications over time, which can help inform training of healthcare professionals and provide evidence for the effect of any changes. Of course, this functionality may have the opposite effect and encourage intended recipients (i.e. physicians/prescribers) to avoid reading messages altogether, which needs to be taken into account when monitoring the impact of changes.

Finally, receipt of requests was found to be influenced by the presence of the pharmacist to prompt physician review. This was supported by findings from the quantitative analysis,

which found that the time taken for physicians to action requests significantly increased over the weekend (compared to a Monday) when the pharmacist was not ward-based to follow these up and decreased in settings covered by a pharmacist for the majority of the day (e.g. Medical Admissions). These findings highlight the importance of a seven day ward-based pharmacy service to support prescribers (and other staff) through the medication process and reinforces this recommendation made by NHS England to transform services in acute hospitals (Office of the Chief Pharmaceutical Officer, 2016). The presence of the pharmacist can prompt timelier review of medication-related problems, increase the opportunity for direct interaction with the physician and increase the physician's familiarity with a number of pharmacists as they move across numerous patients and wards out-of-hours, both of which can promote collaborative working. In the first instance, staff resource could be allocated at weekends to those areas where a high activity in the assignment of messages is observed (Medical Specialities), a higher prevalence of high-risk errors (General Medicine) and where most discrepancies are identified through reconciliation (Medical Admissions).

9.2.3.2 Actioning the request

Just over a third of messages led to an action as requested by the pharmacist and just over half of these were actioned within 24 hours. Upon receipt of a request, an action in response to a pharmacists' request was found to be dependent on the physician's ability (or confidence) to make a decision and this was found to be largely dependent on their access to information about a patient. This was further emphasised when physicians were asked to make decisions about patients that were not directly under their care, such as at weekends when the time taken to action messages increased (compared to a Monday). Messages

relating the reconciliation process were more likely to be actioned, in contrast to those assigned to high-risk medicines. The former of the two may be easier for physicians to rectify with the information provided by the pharmacist, compared to requests relating to the latter, where consulting colleagues to confirm the status of the prescription may be chosen as a safer course of action. The time taken for some requests to be actioned supports the use of the message function for low-risk requests only—a practice adopted by the pharmacists, aware that messages can be overlooked. It also supports the limited use of the function in areas of the hospital that may not be well supported by a regular ward-based pharmacist.

Awareness of the context of prescribing over time was found difficult (sometimes impossible) to gather in the CPOE system, since there was no dedicated function within the systems to encourage this documentation in a single place. Some physicians and prescribing pharmacists at UHBFT adopted workarounds to communicate rationale for changes they had made so these were visible to other staff. A function to document a chronological timeline of medication-related changes within the CPOE system would allow for a more comprehensive overview of a patient's management (van der Linden *et al*., 2012). Access to this information could help physicians make decisions about patients who are not directly under their care (such as at weekends), enable requests to be actioned in a timelier manner and reduce the risk of second order errors. Pharmacists would also benefit from access to the information, reducing the need to request clarification for prescribing decisions.

The messages assigned by pharmacists had a median length of only 45 characters, a quarter of the possible length of 255 characters. This did not appear to affect the clarity of the

communication, with messages being understood by the physicians (and other pharmacists), as well as being easily understood during the analysis of content for the development of the database. Fewer characters will inevitably reduce the time required to write and read the messages and may, therefore, facilitate a less interruptive workflow. However, the level of detail provided to inform decision-making is questionable. For example, the majority of messages themed as providing 'Supporting Information' communicated information about a patient's usual regimen taken at home, without an explicit request to make a change to the prescription. This may highlight an issue regarding the completeness of written communications and the need to clearly state the desired outcome, i.e. the recommendation. Although this was not raised during the focus groups, the provision of this information could provide more context to the request for the recipient of the message and, as such, the physician may feel better informed to act. 'SBAR' (Situation, Background, Assessment and Recommendation) is a method of structuring a communication to ensure that the information is complete and the desired response (recommendation) is clear (Dayton & Henriksen, 2007). This approach helps focus the sender of the information to make clear the purpose of the communication and the desired outcome, which also makes it easier for the recipient to act. 'SBAR' can also encourage a more consistent approach between healthcare staff (Leonard *et al.*, 2004) and its use has been shown to positively correlate with in-hospital survival when text messages are sent between nurses and physicians (Wong *et al.*, 2017). Although not directly analysed in this study, all four elements of SBAR would likely not be possible in just 45 characters. Training pharmacists to use SBAR for their written communications could encourage a more appropriate use of the message function, reserving it only for those with explicit recommendations and not just the provision of information. The structured communication

would encourage pharmacists to provide more context (S: Situation; B: Background), which may facilitate physician decision-making. Communication functions could be designed to prompt each of the four elements to ensure clear exchange of information.

The grade of the pharmacist was found to influence the acceptance of review messages, with those assigned by grade 8 more likely to be actioned and those assigned by grade 7 in a timelier manner (≤24 hours). This is interesting considering the messages assigned by grade 8 pharmacists were significantly shorter in length than those assigned by grades 6 and 7 and they assigned proportionally fewer than any other grade. Grade 8 pharmacists are more likely to be assigned to the same setting over a long period of time, compared to grade 6 pharmacists who frequently rotate across specialities. One possible explanation is that personal presence is important for developing working relationships and that this is important when being asked to respond to requests and make decisions. This reinforces the importance of ward-based pharmacists being part of the multidisciplinary team—even more important when a pharmacist is new to a setting or ward. Ward rounds provide a platform through which to build a working relationship with the team and gain more context about the patients under their care. Pharmacists' attendance would increase the opportunity for personal interaction, encourage collaborative working and potentially increase the effectiveness of requests communication asynchronously.

9.2.3.3 Closing the communication

There is evidence to suggest that physicians do not always implement the pharmacists' advice in practice (Estellat *et al.*, 2007; Mannheimer *et al.*, 2006), which may be for valid clinical reasons. Unfortunately, given the lack of functionality to provide feedback within

the CPOE system at UHBFT, the reasons why requests were not actioned remain unknown, as they often do to the pharmacists assigning the message. The review of the literature (section 2.3.2.1) found that two-way communication was perceived as beneficial since it could allow for better coordination of tasks and help maintain an awareness of the stages of the medication process (Ash *et al.*, 2004; Dykstra, 2002). Consistent with these findings, uni-directional communication was found to impact on the pharmacist's workload, since there was a need to follow-up the outcome of requests owing to uncertainty about whether they had been received and acknowledged (8.4.2.4). Physicians expressed a desire to be able to respond to messages so that the pharmacist did not feel their requests were ignored. Incorporating two-way communication into CPOE systems could enhance the flow of information, which in turn could help manage workload and enhance the coordination of care. The written feedback also encourages documentation, which can provide further context for decisions-making in the medication process (Chused *et al.*, 2008).

The sign-off of messages is intended to be used by physicians to remove the 'R' icon from a prescription when the request has been dealt with or the information considered. A low rate of sign-off of messages was observed with the CPOE system at UHBFT, with just under half signed-off as would be intended by system design and desired by the pharmacist as a form of feedback. In addition, over a third of these messages were also found to be signed-off by pharmacists themselves. In isolation, this would suggest that the review message function is not always utilised by the physician as an acknowledgment that the information from the pharmacist has been read and/or actioned and could highlight a sub-optimal communication. However, the focus groups identified a gap in knowledge relating to the use of the review message function—specifically concern among physicians that the

messages would disappear if they were signed-off and would therefore not be available as a form of clinical documentation to provide context for any changes made to prescriptions for other practitioners. The training provided to healthcare professionals on the use of CPOE systems should include interprofessional communication and how to coordinate care in this environment. This knowledge is best gained through interprofessional training, so that practitioners can understand how each other use the system to communicate and their expectations of use. Figure 9.1 summarises the process of communication in the context of CPOE with the capability to send uni-directional electronic communications and the factors affecting each of the steps identified. Note that an action may be the decision to take 'no action' in this context.

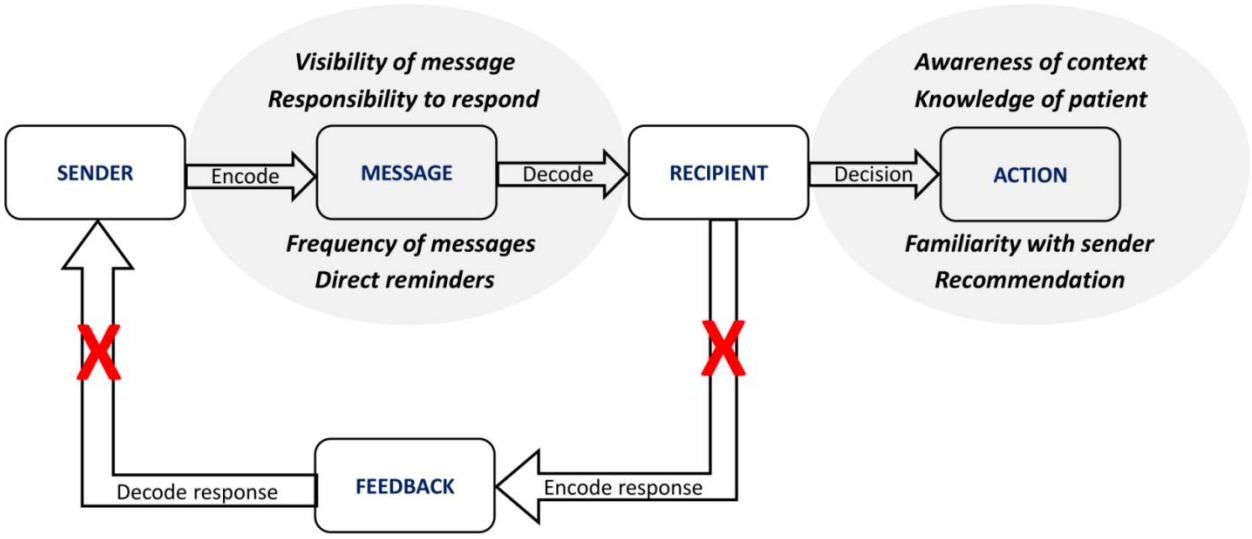


Figure 9.1 – Process of communication in the context of CPOE and electronic messaging at UHBFT

9.2.4 Summary of recommendations

Figure 9.2 summarises the recommendations at each of the steps of the communication process. This is further detailed in Table 9.1, including potential outcomes of each of the recommendations.

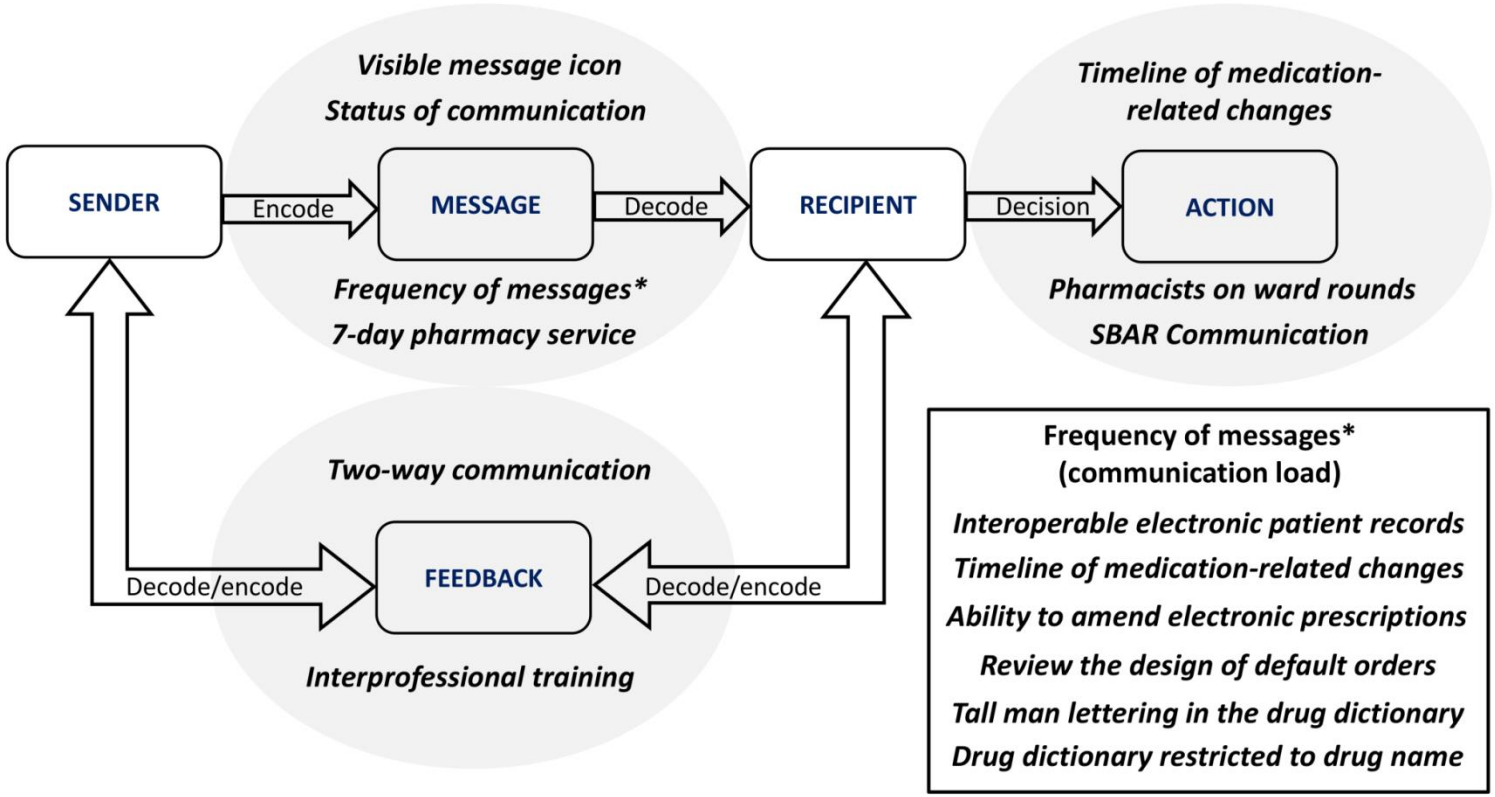


Figure 9.2 – Summary of recommendations to optimise communication at various stages of the process

Table 9.1 – Summary of recommendations and potential outcomes

Stage in process	Factor	Recommendation	Outcome
Receipt of the message	Visibility of the message	Optimise the design of the message icon so that it is clearly associated with pharmacy	Reduce the risk of confusability of the message icon with other message functions
	Responsibility to respond	Messages designed to that the status can be determined (e.g. opened, acknowledged)	Encourages ownership of the message and facilitates follow-up
	Frequency of messages	Integration and interoperability of electronic patient records	Reduce frequency of messages requesting clarification
		Timeline of medication-related changes and associated rationale	Reduce frequency of messages requesting clarification
		Ability to amend electronic prescriptions	Reduce frequency of messages to request low-risk (fine tuning) of prescriptions
		Review the extent to which orders provide default information	Reduce the risk of errors from default orders
		Tallman lettering in drug dictionaries	Reduce the risk of selection errors
		Drug dictionary restricted to medicine name only	Reduce the risk of selection errors
	Direct reminders	Seven day ward-based pharmacy service	Pharmacist available to prompt review of messages
Action of requests	Awareness of context	Timeline of medication-related changes and associated rationale	Knowledge to build the patient story
		Use of SBAR communication	Knowledge to build the patient story
	Knowledge of patient	Timeline of medication-related changes and associated rationale	Knowledge to build the patient story
		Interoperable electronic patient records	Knowledge to build the patient story
	Familiarity with the sender	Pharmacists attendance at ward rounds	Promote collaborative working
	Recommendation	Use of SBAR communication	Knowledge to build the patient story
Feedback	Capability to provide feedback	Two-way communication	Promote collaborative working

9.2.5 Barriers to the implementation of recommendations

Some of the technological recommendations I have made will not be within the control of local hospital sites to implement. Hospitals with locally developed ('home grown') systems, such as that used at UHBFT, will have more power to configure systems to apply the technological changes. However, such organisations may be constrained by staff time and the finances required to support this. Hospitals using commercial systems may have less immediate control, but changes may be possible in the longer-term if organisations work collaboratively with their software developers (Cresswell *et al.*, 2014). The re-design or introduction of new capabilities within CPOE systems will require staff training to ensure optimal use (Baysari *et al.*, 2012; Mozaffar *et al.*, 2017; Redwood *et al.*, 2011) and depending on the complexity of the change, this may require additional resource. The recommendation to introduce communication and coordinated care tasks into training and for this to be approached interprofessionally, would also require existing training programmes to be modified, which would require staff resource.

Some recommendations may require a change of culture in organisations. For example, the introduction of pharmacists at ward rounds may face barriers from healthcare professionals who are already in attendance and from the pharmacy department in relation to the time required to be allocated for such activities. The implementation of a seven-day pharmacy service may also face barriers, such as workforce capability and funding (Office of the Chief Pharmaceutical Officer, 2016). However, it is positive that both these recommendations are strongly supported by NHS England and are outlined as necessary steps to meet the clinical standards outlined for seven day services, particularly 'Standard 8: Ongoing Review' (NHS

England, 2016). This may provide the stimulus needed to make the initial steps to transform clinical pharmacy services in the NHS.

Finally, the use of SBAR communication would require much broader education and training, targeting both undergraduate pharmacy and technician students and the qualified pharmacy workforce. To achieve this nationally, it may need to be reflected in standards published by the General Pharmaceutical Council. The current workforce would also need to be trained. Re-designing communication functions to prompt each of the four elements of the communication tool could facilitate implementation.

9.3 Strengths and limitations

The strengths and limitations of the studies have been presented at the end of each chapter throughout the thesis, the main points of which are summarised here.

One of the main strengths of this research is the methodological design. A sequential mixed-methods approach was adopted, comprised first of a quantitative analysis of pharmacist messages assigned to prescriptions in a large acute hospital, followed by qualitative research using focus groups and observation of pharmacists on the wards and in the dispensary, to both complement and expand on the findings (Holman, 1993; p29-36; Venkatesh *et al.*, 2013). This approach allows for a deeper exploration of concepts and was considered particularly important for investigating communication, where a quantitative analysis of messages alone would not be able to provide context in which these were sent and why.

The quantitative analysis of pharmacist-physician communications comprised over 34,000 written messages, including detailed information relating to their associated prescriptions and where applicable, subsequent actions. The volume and veracity of the database is a strength of the study and, despite the subjective interpretation of messages during the content analysis, a high inter-rater reliability was demonstrated. Nevertheless, the study was conducted in a single-centre (UHBFT) using a locally developed CPOE system and as such the results may not necessarily reflect the practice of pharmacists in other hospital settings that use CPOE and electronic communication. The free-text review messages were analysed and coded to identify the explicit subject of the discourse and not the latent content (i.e. what is implied). Latent analysis is not possible without knowing the individual pharmacists and running an analysis of their intent and the subsequent interpretation of the recipient. A lack of context at the time of the message (i.e. of the patient and the situation) also makes this analysis difficult and prevents further investigation into whether an error had actually occurred and the potential impact of this on patient care and safety.

The focus groups were conducted in two hospitals and the observational research of pharmacists undertaking their usual clinical duties in one of these—both in the same country. Despite evidence that data saturation was achieved, the findings may not be transferable to all hospitals or countries outside of England. First, the impact of the factors identified in this study may vary according to the complexity of the systems in use. Second, clinical pharmacy services vary between countries, where even in those with well-established healthcare, the main task of the pharmacist still focuses on dispensing (Perraudin *et al.*, 2011). A strength of this study was the steps taken to reduce the risk of methodological and confirmation bias. The data were independently coded by a second

researcher and an independent researcher was introduced to facilitate the focus groups to ensure the discussion was not inappropriately bias. Multiple researchers were also recruited to observe the pharmacists at work. This was conducted to improve the reliability of the study, to gain different perspectives and interpretation of the findings, as well as to increase the number of hours of observation over a period of time.

Finally, verbal communication between the pharmacist and physician was not investigated, though this was occasionally observed during the observational research. The proportion of interventions made directly compared to asynchronously is unknown, but the focus group data did provide a good insight into this and why the modality of communication is selected over other methods.

9.4 Future work

9.4.1 Ongoing dissemination

In the first instance, it is essential that the findings from this research are fed back to hospitals, organisations and system developers that are in a position to influence change. This can be achieved through publication and with posters and presentations at National and international conferences. Dissemination is a requirement of the NIHR fellowship and is actively encouraged during annual reviews. The final qualitative chapter in this thesis will be prepared and submitted for publication to complete the dissemination of both the quantitative and qualitative studies in peer reviewed journals.

The findings from this research have been fed back to the Director of Pharmacy at UHBFT and the CPOE team at the hospital so that technical changes to the system can be considered. Plans have also been made to present the findings to the Royal Pharmaceutical Society Boards of England, Wales and Northern Ireland and an invitation has been accepted to further present this to the 'Pharmacy Digital Forum', a group that feedback to the country boards on matters relating to information technology.

9.4.2 Implementation and ongoing research

One of the recommendations to reduce the communication load of pharmacists was to permit changes to electronic prescriptions, in the same way that this would be conducted on paper. I suggested the development of standards to ensure this practice is implemented consistently and safely. This would require for consensus to be reached, with expert input from both pharmacists and physicians using a nominal group technique or Delphi (McMillan *et al.*, 2016). The implementation would need to be piloted and closely monitored and the changes pharmacists make auditable. As preliminary work to inform this recommendation, I have submitted a Year 4 research project to the Master of Pharmacy (MPharm) degree at the University of Birmingham to investigate the amendments pharmacists make to prescriptions in a paper-based prescribing environment. The themes identified in this study (commencing October 2017) will provide valuable data to inform a Delphi process with input from pharmacists and physicians of varying experience and specialisms from across the country.

Integration of EPRs into undergraduate education has been recommended throughout this discussion, specifically in relation to improving digital competence in the use of the

technology and the use of SBAR when communicating electronically. To raise awareness of both the benefits and unintended consequences of CPOE, three lectures have been integrated into the MPharm degree at the University of Birmingham, all of which I developed and deliver on an annual basis. In Year 1, I introduce the digitisation of prescriptions in the community and hospital setting and present the policies and reports that have driven and are driving, a paperless NHS. In Year 3, I introduce the benefits and unintended consequences of the technology and discuss pharmacist-physician communication in the context of CPOE, which encompasses the importance of SBAR communication. Although this teaching is beneficial to students at Birmingham, a wider approach is needed to achieve an impact on practice. In July 2016, the Prescribing Lead at the University of Manchester and I established a National working group to focus on the education of undergraduate healthcare professionals in acquiring the clinical, social and technical skills to safely prescribe and manage medicines with and alongside EPRs. As a group comprising 12 academic institutions, representation from NHS England, NHS Digital and system suppliers, we have explored and developed key principles for the education of undergraduate healthcare students in the context of EPRs and outlined associated competencies. This work was accepted for oral presentation at the European Association for Clinical Pharmacology and Therapeutics (24–27 June 2017) and has recently been endorsed by the Royal Pharmaceutical Society. The principles and competencies will be prepared for publication, which is the first step in the process of integrating EPRs into undergraduate health education related to medicines safety. These will be used to develop simulated patient records and associated scenarios, which we plan to make available to medical educators nationally via a web-based community of practice. I have initiated applications to apply for funding to support the on-going work related to this project. To

gain a greater insight into the perceptions of healthcare students regarding the current and future digitisation of patient records in the NHS I have also submitted an additional two Year 4 MPharm research projects. After a focused review of the literature, the students will conduct qualitative interviews with medical, pharmacy and nursing students about electronic patient records.

The technological changes recommended here will need ongoing evaluation to monitor their impact and to identify unintended and unanticipated consequences that may compromise communication and put patients at risk. Analysis of electronic communications can provide an insight into how modifications affect communication load, particularly relating to lower-risk errors and the use of CDS. An ethnographic study of physicians' interactions with the CPOE system and communications at the point of prescribing would provide further insight into how the organisational, individual, social and technical factors interact (Redwood *et al.*, 2011).

The rate of high-risk errors amendable to CDS at UHBFT was found to be low. This is potentially because such errors are discussed directly with the physician to ensure they are rectified in a timely manner. In view of this, the analysis of pharmacist messages cannot be used as a reliable method to determine the true incidence of high-risk errors in a hospital setting. Further research would be beneficial to understand the occurrence of these errors in NHS hospitals. This could be achieved through a prospective analysis of inpatient prescription orders or a retrospective review of prescribing data captured from CPOE systems. The findings from this research could be used to inform organisations about the

potential for patient harms from prescribing and guide the design and configuration of systems to optimise CDS to reduce the rate of high-risk errors.

Finally, it would be beneficial to conduct research into the modalities of communication available in CPOE systems used by NHS hospitals. Communication is a capability assessed by NHS England in the annual 'Digital Maturity Assessment' (NHS England, 2015). Data from this assessment could help identify systems that can be optimised, but also exemplar systems that could be used to conduct further comparative research. Importantly, this research could inform the generalisability of the findings described in this thesis.

9.5 Final conclusions

The aim of this research was to understand how the use of CPOE and CDS in the hospital setting have an impact on pharmacist-physician communication. The technology was found to change the focus and frequency of communications between the pharmacist and the physician. The latter of the two causing an increased workload for the two professionals. The electronic documentation of the medication process does not entirely reflect the work that would have been conducted on paper-based systems (i.e. drug charts). The technology largely removes the ability for pharmacists to amend prescriptions, which on paper helped clarify information for the physician to inform the administration or monitoring of medication and importantly allowed for prescriptions to be fine-tuned to reflect the patient's requirements. The loss of this capability means that such amendments are now the remit of the physician and are required to be communicated by the pharmacist. The system restriction increases workload and, owing to the additional step in the process, can

lead to delays in amendments being made. This has the potential to impact on the patient's treatment regimen during admission and their seamless transition at the interface of care.

CDS-related errors were found to increase communication load for the pharmacist and subsequent workload for the physician. The design and/or local configuration of systems with respect to functions such as default orders need to be reviewed as a matter of priority to ensure patients are aligned to their usual or intended regimens soon after admission. The time dedicated to rectifying such errors can then be directed to more proactive tasks such as optimising treatment regimens for patients to improve outcomes.

The ability to communicate asynchronously via the CPOE system and assign messages directly to prescriptions is beneficial for the work of both the pharmacist and physician. The capability provides a means of clinical documentation, serving as a visual prompt at the point of prescribing and as a reminder of the details of the request. The visibility of messages to all members of the healthcare team also facilitates a non-interruptive workflow and more effective coordination of tasks—though the latter will be dependent on its effective integration into training. It is important that asynchronous modalities of communication do not replace direct interactions—rather it is used as an alternative modality for low-risk communications that do not warrant immediate attention and the need to interrupt the physician. Communication functions can be optimised with the capability for the recipient to provide feedback. This would not only facilitate the documentation of the decision-making process, but would be beneficial for encouraging collaborative working.

Finally, the use of CPOE did not encourage remote working of the two professionals. Pharmacists and physicians continued to ensure they were patient-facing and present on the wards to interact with other healthcare professionals. It is important that this way of working is maintained by organisations so that CPOE does not encourage a move to remote working. The personal presence is important for professional interaction and for consulting with patients and their relatives/carers regarding the optimisation of treatment during hospital admission.

REFERENCES

Aarts, J., Ash, J. and Berg, M. (2007) Extending the understanding of computerized physician order entry: implications for professional collaboration, workflow and quality of care. **Internation Journal of Medical Informatics**, 76 Suppl 1: S4-13.

Abbott, M. L. and McKinney, J. (2013) **Understanding and Applying Research Design**. 1st Edn. John Wiley & Sons.

Ackermann, E. W. (1996) The Quality in Australian Health Care Study. **Medical Journal Australia**, 164 (5): 315.

Ahmed, Z., McLeod, M., Barber, N., et al. (2013) The use and functionality of electronic prescribing systems in English acute NHS trusts: a cross-sectional survey. **PLoS ONE**, 8: e80378.

Al-Jeraisy, M. I., Alanazi, M. Q. and Abolfotouh, M. A. (2011) Medication prescribing errors in a pediatric inpatient tertiary care setting in Saudi Arabia. **BMC Research Notes**, 14 (4): 294.

Amato, M. G., Salazar, A., Hickman, T-T. T., et al. (2017) Computerized prescriber order entry–related patient safety reports: analysis of 2522 medication errors. **Journal of the American Medical Informatics Association**, 24 (2): 316-322.

American Society of Hospital Pharmacists (ASHP) (1993) **ASHP Guidelines on Preventing Medication Errors in Hospitals** [online]. http://www.ashp.org/DocLibrary/BestPractices/MedMisGdlHosp.aspx [Accessed 8 March 2012].

Armstrong, D., Gosling, A., Weinman, J., et al. (1997) The place of inter-rater reliability in qualitative research: An empirical study. **Sociology,** 31 (3): 597-606.

Ash, J., Gorman, P. N., Hersh, R. W., et al. (1999) Perceptions of house officers who use physician order entry. **AMIA 1999 Annual Symposium Proceedings**: 471-475.

Ash, J. S., Berg, M. and Coiera, E. (2004) Some Unintended Consequences of Information Technology in Health Care: The Nature of Patient Care Information System-related Errors. **Journal of the American Medical Informatics Association**, 11 (2): 104-112.

Ashcroft, D. and Cooke, J. (2006) Retrospective analysis of medication incidents reported using an on-line reporting system. **Pharmacy World & Science**, 28 (6): 359-365.

Atkins, J. (2002) Interprofessional education: today, yesterday and tomorrow. **Learning in Health & Social Care,** 1: 172-176.

Avery, A. J., Dex, G. M., Mulvaney, C., et al. (2011) Development of prescribing-safety indicators for GPs using the RAND Appropriateness Method. **British Journal of General Practice**, 61 (589): e526-e536.

Avery, A. J., Savelyich, B. S. P., Sheikh, A., et al. (2005) Identifying and establishing consensus on the most important safety features of GP computer systems: e-Delphi study. **Informatics in Primary Care**, 13 (1): 3-12.

Avery, T., Barber, N., Ghaleb, M. A., et al. (2012) I**nvestigating the prevalence and causes of prescribing errors in general practice: The PRACtICe Study.** GMC Publication 1-5-2012. General Medical Council, London.

Barber, N., Batty, R. and Ridout, D. (1997) Predicting the rate of physician-accepted interventions by hospital pharmacists in the United Kingdom. **American Journal of Health-System Pharmacy**, 54 (4): 397-405.

Barber, N., Cornford, T. and Klecun, E. (2007) Qualitative evaluation of an electronic prescribing and administration system. **Quality & Safety in Health Care**, 16: 271-278.

Barber, N., Frankin, B., Cornford, T., et al. (2006) **Safer, Faster, Better? Evaluating Electronic Prescribing**. Report to the patient safety research programme. Department of Information Systems, London School of Economics & Political Science.

Bardram, J. and Hansen, T. (2010) Context-Based Workplace Awareness. **Computer Supported Cooperative Work** (CSCW), 19 (2): 105-138.

Barker, K. N., Flynn, E. A., Pepper, G. A., et al. (2002) Medication errors observed in 36 health care facilities. **Archives of Internal Medicine**, 162 (16): 1897-1903.

Basey, A. J., Krska, J., Kennedy, T. D., et al. (2013) Prescribing errors on admission to hospital and their potential impact: a mixed-methods study. **BMJ Quality & Safety**, 23 (1): 17-25.

Bates, D. W., Leape, L. L., Cullen, D. J., et al. (1998) Effect of computerized physician order entry and a team intervention on prevention of serious medication errors. **JAMA**, 280 (15): 1311-1316.

Bates, D. W., Teich, J. M., Lee, J., et al. (1999) The impact of computerized physician order entry on medication error prevention. **Journal of the American Medical Informatics Association**, 6 (4): 313-321.

Baysari, M. T., Reckmann, M. H., Li, L., et al. (2012) Failure to utilize functions of an electronic prescribing system and the subsequent generation of 'technically preventable' computerized alerts. **Journal of the American Medical Informatics Association**, 19 (6): 1003-1010.

Baysari, M. T., Tariq, A., Day, R. O., et al. (2017) Alert override as a habitual behavior – a new perspective on a persistent problem. **Journal of the American Medical Informatics Association**, 24 (2): 409-412.

Bedouch, P., Tessier, A., Baudrant, M., et al. (2011) Computerized physician order entry system combined with on-ward pharmacist: analysis of pharmacists' interventions. **Journal of Evaluation in Clinical Practice**, 18 (4): 911-918.

Beeler, P. E., Bates, D. W. and Hug, B. L. (2014) Clinical decision support systems. **Swiss Med Wkly**, 144: w14073.

Beuscart-Zephir, M. C., Pelayo, S., Anceaux, F., et al. (2005) Impact of CPOE on doctor-nurse cooperation for the medication ordering and administration process. **International Journal of Medical Informatics**, 74 (7-8): 629-641.

Bjorkman, I. K., Sanner, M. A. and Bernsten, C. B. (2008) Comparing four classification systems for drug-related problems: processes and functions**. Research in Social & Administrative Pharmacy**, 4 (4): 320-331.

Blandford, A., Furniss, D. and Vincent, C. (2014) Patient safety and interactive medical devices: Realigning work as imagined and work as done**. Clinical Risk**, 20 (5): 107-110.

Blumenthal , D. and Tavenner , M. (2010) The "Meaningful Use" Regulation for Electronic Health Records. **New England Journal of Medicine**, 363 (6): 501-504.

Bobb, A., Gleason, K., Husch, M., et al. (2004) The epidemiology of prescribing errors: the potential impact of computerized prescriber order entry. **Archives of Internal Medicine,** 164 (7): 785-792.

Boonstra, A. and Broekhuis, M. (2010) Barriers to the acceptance of electronic medical records by physicians from systematic review to taxonomy and interventions**. BMC Health Services Research**, 10 (1): 231.

Bourne, R. and Choo, C. (2012) Pharmacist proactive medication recommendations using electronic documentation in a UK general critical care unit. **International Journal of Clinical Pharmacy**, 34 (2): 351-357.

Bradley, E. H., Curry, L. A. and Devers, K. J. (2007) Qualitative data analysis for health services research: developing taxonomy, themes and theory. **Health Services Research**, 42 (4): 1758-1772.

Brown, C. L., Mulcaster, H. L., Triffitt, K. L., et al. (2017) A systematic review of the types and causes of prescribing errors generated from using computerized provider order entry systems in primary and secondary care**. Journal of the American Medical Informatics Association**, 24 (2): 432-440.

Brown, C. L., Reygate, K., Slee, A., et al. (2016) A literature review of the training offered to qualified prescribers to use electronic prescribing systems: why is it so important? **International Journal of Pharmacy Practice**, 25(3): 195-202.

Brown, P. J. (2014) What do Physicians Read (and Ignore) in Electronic Progress Notes? **Applied Clinical Informatics**, 5 (2): 430-444.

Brown, P. J., Marquard, J. L., Amster, B., et al. (2014) What do Physicians Read (and Ignore) in Electronic Progress Notes? **Applied Clinical Informatics**, 5 (2): 430-444.

Campbell, E. M., Sittig, D. F., Ash, J. S., et al. (2006) Types of unintended consequences related to computerized provider order entry. **Journal of the American Medical Informatics Association**, 13 (5): 547-556.

Caruba, T., Colombet, I., Gillaizeau, F., et al. (2010) Chronology of prescribing error during the hospital stay and prediction of pharmacist's alerts overriding: a prospective analysis. **BMC Health Services Research**, 10: 13.

Castro, G. M., Buczkowski, L., Hafner, J. M. (2016) The Contribution of Sociotechnical Factors to Health Information Technology-Related Sentinel Events. **Joint Commission Journal on Quality & Patient Safety**, 42 (2): 70-76.

Chen, C. I., Liu, C. T., Chen, C. F., et al. (2004) Medical errors in a hospital in Taiwan: Incidence, aetiology and proposed solutions. **Journal on Information Technology in Healthcare**, 2 (1): 11-18.

Chused, A. E., Kuperman, G. J. and Stetson, P. D. (2008) Alert Override Reasons: A Failure to Communicate. **AMIA Annual Symposium Proceedings**, 2008: 111-115.

Classen, D., Phansalkar, S. and Bates, D. (2011) Critical drug-drug interactions for use in electronic health records systems with computerized physician order entry: review of leading approaches. **Journal of Patient Safety**, 7 (2): 61-65.

Cochrane. PICO Ontology. [online] http://linkeddata.cochrane.org/pico-ontology [Accessed Oct 2012].

Coiera, E. and Tombs, V. (1998) Communication behaviours in a hospital setting: an observational study. **BMJ**, 316 (7132): 673-676.

Coleman, J. J., Hodson, J., Brooks, H. L., et al. (2013) Missed medication doses in hospitalised patients: a descriptive account of quality improvement measures and time series analysis. **International Journal for Quality in Health Care**, 25 (5): 564-572.

Coleman, J. J., Hodson, J., Thomas, S. K., et al. (2015) Temporal and other factors that influence the time doctors take to prescribe using an electronic prescribing system. **Journal of the American Medical Informatics Association**, 22 (1): 206-212.

Colpaert, K., Claus, B., Somers, A., et al. (2006) Impact of computerized physician order entry on medication prescription errors in the intensive care unit: A controlled cross-sectional trial. **Critical Care**, 10 (1) (R21).

Cook, K. E. (2012) Reliability assessments in qualitative health promotion research. **Health Promotion International**, 27 (1): 90-101.

Cooper, R., Guillaume, L., Avery, T., et al. (2008) Non-medical prescribing in the United kingdom: developments and stakeholder interests. **The Journal of Ambulatory Care Management**, 31 (3): 244-252.

Cousins, D. and Hatoum, H. (1991) The development of a computerised quality assurance system for clinical pharmacy. **International Journal of Pharmacy Practice**, 1 (2): 86-89.

Cousins, D. H., Gerrett, D. and Warner, B. (2012) A review of medication incidents reported to the National Reporting and Learning System in England and Wales over six years (2005 – 2010). **British Journal of Clinical Pharmacology**, 74 (4): 597-604.

Cresswell, K., Coleman, J., Slee, A., et al. (2013a) Investigating and Learning Lessons from Early Experiences of Implementing ePrescribing Systems into NHS Hospitals: A Questionnaire Study. **PLoS ONE**, 8 (1): e53369.

Cresswell, K. M., Bates, D. W. and Sheikh, A. (2013b) Ten key considerations for the successful implementation and adoption of large-scale health information technology. **Journal of the American Medical Informatics Association**, 20 (e1): e9-e13.

Cresswell, K. M., Bates, D. W., Williams, R., et al. (2014) Evaluation of medium-term consequences of implementing commercial computerized physician order entry and clinical decision support prescribing systems in two 'early adopter' hospitals**. Journal of the American Medical Informatics Association**, 21(e2):e194-202.

Cresswell, K. M., Mozaffar, H., Lee, L., et al. (2016) Workarounds to hospital electronic prescribing systems: a qualitative study in English hospitals. **BMJ Quality & Safety**. Publised online first: 29 April 2017

Creswick, N. and Westbrook, J. I. (2015) Who do hospital physicians and nurses go to for advice about medications? A social network analysis and examination of prescribing error rates. **Journal of Patient Safety**, 1;11(3):152-9.

Crowe, S., Cresswell, K., Avery, A. J., et al. (2010) Planned implementations of ePrescribing systems in NHS hospitals in England: a questionnaire study. **JRSM Short Reports**, 1 (4): 33.

Dayton, E. and Henriksen, K. (2007) Communication Failure: Basic Components, Contributing Factors and the Call for Structure. **The Joint Commission Journal on Quality and Patient Safety**, 33 (1): 34-47.

De Winter, S., Spriet, I., Indevuyst, C., et al. (2010) Pharmacist- versus physician-acquired medication history: a prospective study at the emergency department. Quality and Safety in Health Care, 19 (5): 371-375.

Dean, B. and Barber, N. (1999) A validated, reliable method of scoring the severity of medication errors. **American Journal of Health-System Pharmacy**, 56 (1): 57-62.

Dean, B., Barber, N. and Schachter, M. (2000) What is a prescribing error? **Quality in Healthcare**, 9 (4): 232-237.

Dean, B., Schachter, M., Vincent, C., et al. (2002a) Causes of prescribing errors in hospital inpatients: a prospective study. **Lancet**, 359.

Dean, B., Schachter, M., Vincent, C., et al. (2002b) Prescribing errors in hospital inpatients: their incidence and clinical significance. **Quality & Safety in Healthcare**, 11 (4): 340-344.

Dearden, E., Mellanby, E., Cameron, H., et al. (2015) Which non-technical skills do junior doctors require to prescribe safely? A systematic review**. British Journal of Clinical Pharmacology**, 80(6): 1303-1314.

Department of Health, L. (2015) Start Smart - Then Focus: Antimicrobial Stewardship Toolkit for English Hospitals London. [online]. https://www.ficm.ac.uk/sites/default/files/FICM-Start_Smart_Then_Focus_FINAL.pdf [Accessed March 2015].

Department of Health (2000) Pharmacy in the Future –**Implementing the NHS Plan. A programme for pharmacy in the National Health Service**. London. [online]. http://webarchive.nationalarchives.gov.uk/20121013030701/http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/@dh/@en/documents/digitalasset/dh_4068204.pdf [Accessed May 2015].

Devine, E. B., Wilson-Norton, J. L., Lawless, N. M., et al. (2007) Characterization of prescribing errors in an internal medicine clinic. **American Journal of Health System Pharmacy**, 64 (10): 1062-1070.

Dixon-Woods, M., Redwood, S., Leslie, M., et al. (2013) Improving Quality and Safety of Care Using "Technovigilance": An Ethnographic Case Study of Secondary Use of Data from an Electronic Prescribing and Decision Support System. **The Milbank Quarterly**, 91 (3): 424-454.

Donyai, P., O'Grady, K., Barber, N., et al. (2007) The effects of electronic prescribing on the quality of prescribing. **British Journal of Clinical Pharmacology**, 62 (2): 230-237.

Dooley, M. J., Allen, K. M., Doecke, C. J., et al. (2004) A prospective multicentre study of pharmacist initiated changes to drug therapy and patient management in acute care government funded hospitals. **British Journal of Clinincal Pharmacolology**, 57 (4): 513-521.

Dornan, T., Ashcroft, D., Heathfield, H., et al. (2009) **An in depth investigation into causes of prescribing errors by foundation trainees in relation to their medical education**. EQUIP study. London: General Medical Council.

Dykstra, R. (2002) Computerized Physician Order Entry and Communication: Reciprocal Impacts. **AMIA 2002 Annual Symposium Proceedings**. 230–234.

Edwards, A., Fitzpatrick, L.-A., Augustine, S., et al. (2009) Synchronous communication facilitates interruptive workflow for attending physicians and nurses in clinical settings. International Journal of Medical Informatics, 78 (9): 629-637.

EHR IMPACT (2009) **The socio-economic impact of interoperable electronic health record (EHR) and ePrescribing systems in Europe and beyond** [online]. http://www.ehr-impact.eu/downloads/documents/EHRI_final_report_2009.pdf [Accessed 21 Feb 2017].

Elrouby, S. and Tully, M.P. (2017) Using the Behaviour Change Wheel to identify interventions to facilitate the transfer of information on medication changes on electronic discharge summaries. **Research in Social and Administrative Pharmacy**, 13(3), pp.456-475.

Engum, S. A. and Breckler, F. D. (2008) An evaluation of medication errors-the pediatric surgical service experience. **Journal of Pediatric Surgery**, 43 (2): 348-352.

Estellat, C., Colombet, I., Vautier, S., et al. (2007) Impact of pharmacy validation in a computerized physician order entry context. **International Journal of Quality in Health Care**, 19 (5): 317-325.

European Medicines Agency (2014) Good practice guide on recording, coding, reporting and assessment of medication errors. **Pharmacovigilance Risk Assessment Committee**. EMA/762563/2014.

Fern, E. F. (1982) The Use of Focus Groups for Idea Generation: The Effects of Group Size, Acquaintanceship and Moderator on Response Quantity and Quality. **Journal of Marketing Research**, 19 (1): 1-13.

Ferner, R. E. and Aronson, J. K. (2000) Medication errors, worse than a crime. **Lancet**, 355 (9208): 947-948.

Fijn, R., Van den Bemt, P. M., Chow, M., et al. (2002) Hospital prescribing errors: epidemiological assessment of predictors. **British Journal of Clinical Pharmacology**, 53 (3): 326-331.

Fitch, K., Bernstein, S. J., Aguilar, M. D., et al. (2001) **The RAND/UCLA Appropriateness Method**. Santa Monica (CA):.

Ferguson, J., Keyworth, C. and Tully, M.P. (2017) 'If no-one stops me, I'll make the mistake again': Changing prescribing behaviours through feedback; A Perceptual Control Theory perspective. **Research in Social and Administrative Pharmacy** (2 March 2017). Available from http://www.sciencedirect.com/science/article/pii/S1551741116305575?via%3Dihub [EPub ahead of print]

Francis, R. (2013) **Final Report of the Independent Inquiry into Care Provided by Mid Staffordshire NHS Foundation Trust**, January 2005 - March 2009. London. HC375-I.

Franklin, B. D., McLeod, M. and Barber, N. (2010) Comment on 'prevalence, incidence and nature of prescribing errors in hospital inpatients: a systematic review'. **Drug Safety**, 33 (2): 163-165; author reply 165-166.

Franklin, B. D., Reynolds, M., Shebl, N. A., et al. (2011) Prescribing errors in hospital inpatients: a three-centre study of their prevalence, types and causes**. Postgraduate Medical Journal**, 87 (1033): 739-745.

Freemantle, N., Ray, D., McNulty, D., et al. (2015) Increased mortality associated with weekend hospital admission: a case for expanded seven day services? **BMJ**, 351.

Furniss, D., Blandford, A. and Mayer, A. (2011) Unremarkable errors: low-level disturbances in infusion pump use. Proceedings of the 25th BCS conference on human-computer interaction. **British Computer Society.** 197-204

Gagnon, M.-P., Nsangou, É.-R., Payne-Gagnon, J., et al. (2014) Barriers and facilitators to implementing electronic prescription: a systematic review of user groups' perceptions. **Journal of the American Medical Informatics Association**, 21 (3): 535-541.

Gallagher, J., Byrne, S., Woods, N., et al. (2014) Cost-outcome description of clinical pharmacist interventions in a university teaching hospital. **BMC Health Services Research**, 14 (1): 177.

Gallagher, P., Ryan, C., Byrne, S., et al. (2008) STOPP (Screening Tool of Older Person's Prescriptions) and START (Screening Tool to Alert doctors to Right Treatment). Consensus validation. **International Journal of Clinical Pharmacology & Therapeutics**, 46 (2): 72-83.

Garner, M. and Watson, M. C. (2007) Using linguistic analysis to explore medicine counter assistants' communication during consultations for nonprescription medicines. **Patient Education and Counseling**, 65 (1): 51-57.

Gee, J. P. (2014) **An Introduction to Discourse Analysis: Thoery and Method**. Routledge.

General Pharmaceutical Society (2012) **Standards of conduct, ethics and performance** [online]. https://www.pharmacyregulation.org/sites/default/files/standards_of_conduct_ethics_and_performance_july_2014.pdf [Accessed 1 Apr 2017].

General Pharmaceutical Society (2017) **Standards for pharmacy professionals** [online]. https://www.pharmacyregulation.org/sites/default/files/standards_for_pharmacy_professionals_may_2017_0.pdf [Accessed 12 May 2017].

Georgiou, A., Callen, J., Westbrook, J., et al. (2007) Information and communication processes in the microbiology laboratory-implications for Computerised Provider Order Entry. Medinfo 2007: **Proceedings of the 12th World Congress on Health (Medical) Informatics; Building Sustainable Health Systems**. IOS Press. 943

Gerrett, D., Gale, A. G., Darker, I. T., et al. (2009) **The Use of Tall Man Lettering to Minimise Selection Errors of Medicine Names in Computer Prescribing and Dispensing Systems**. Report to the UK National Health Service Connecting for Health Initiative. Leeds: National Health Service. Report No.: ER-07-0612.

Ghaleb, M. A., Barber, N., Dean Franklin, B., et al. (2005) What constitutes a prescribing error in paediatrics? **Quality & Safety in Health Care**, 14 (5): 352-357.

Ghaleb, M. A., Barber, N., Franklin, B. D., et al. (2010) The incidence and nature of prescribing and medication administration errors in paediatric inpatients. Archives of Disease in Childhood, 95 (2): 113-118.

Gill, P. S., Kamath, A. and Gill, T. S. (2012) Distraction: an assessment of smartphone usage in health care work settings. **Risk Management and Healthcare Policy**, 5: 105-114.

Gillespie, U., Alassaad, A., Henrohn, D., et al. (2009) A comprehensive pharmacist intervention to reduce morbidity in patients 80 years or older: A randomized controlled trial. **Archives of Internal Medicine**, 169 (9): 894-900.

Given, L. M., ed (2008) **Peer debriefing**. Thousand Oaks, CA: SAGE Publications Ltd.

Glaser, B. G., Strauss, A. L. (1967) **The discovery of grounded research: strategies for qualitative research**. New Brunswick (USA) and London (UK): Aldine Transaction.

Goodwin MA, Stange KC, Zyzanski SJ, et al. (2001). The Hawthorne effect in direct observation research with physicians and patients. **Jorunal of Evaluation in Clinical Practice,** Available from http://onlinelibrary.wiley.com/doi/10.1111/jep.12781/abstract;jsessionid=2560114058D3372B6EFEADA48589AAE4.f02t01 [EPub ahead of print]

Green, J. and Thorogood, N. (2009) **Qualitative Methods for Health Research**. London: Sage Publications Ltd.

Griffin, F. A. and Resar, R. K. (2009) **IHI Global Trigger Tool for Measuring Adverse Events** (second edition). Cambridge, MA, USA: Institute for Healthcare Improvement.

Gubrium, J. F. and Holstein, J. A., ed, (2001) **Handbook of Interview Research**. SAGE Publications Ltd.

Harrison, M. I., Koppel, R. and Bar-Lev, S. (2007) Unintended Consequences of Information Technologies in Health Care—An Interactive Sociotechnical Analysis. **Journal of the American Medical Informatics Association**, 14 (5): 542-549.

Hartel, M. J., Staub, L. P., Roder, C., et al. (2011) High incidence of medication documentation errors in a Swiss university hospital due to the handwritten prescription process. **BMC Health Services Research**, 11: 199.

Health and Social Care Information Centre (2016) **Prescribing Costs in Hospitals and the Community**, England 2015/16. London. Report No.: ISBN 978-1-78386-875-9.

Heath, C., Svensson, M., Hindmarsh, J., et al. (2002) Configuring Awareness**. Computer Supported Cooperative Work** (CSCW), 11 (3-4): 317-347.

Hohmann, C., Eickhoff, C., Klotz, J. M., et al. (2012) Development of a classification system for drug-related problems in the hospital setting (APS-Doc) and assessment of the inter-rater reliability. **Journal of Clinical Pharmacy & Therapeutics**, 37 (3): 276-281.

Holman, H. R. (1993) Qualitative inquiry in medical research. **Journal of Clinical Epidemiology**, 46 (1): 29-36.

Hoonakker, P. L. T., Carayon, P., Walker, J. M., et al. (2013) The effects of Computerized **Provider Order Entry implementation on communication in Intensive Care Units. International Journal of Medical Informatics**, 82 (5): e107-117.

Hsieh, H.-F. and Shannon, S. E. (2005) Three Approaches to Qualitative Content Analysis. **Qualitative Health Research**, 15 (9): 1277-1288.

Ibáñez-Garcia, S., Rodriguez-Gonzalez, C. G., Martin-Barbero, M. L., et al. (2016) Adding value through pharmacy validation: a safety and cost perspective. **Journal of Evaluation in Clinical Practice**, 22 (2): 253-260.

Ighani, F., Kapoor, K., Gibran, S., et al. (2010) A Comparison of Two-Way Text Versus Conventional Paging Systems in an Academic Ophthalmology Department. **Journal of Medical Systems**, 34 (4): 677-684.

Jayawardena, S., Eisdorfer, J., Indulkar, S., et al. (2007) Prescription errors and the impact of computerized prescription order entry system in a community-based hospital. **American Journal of Therapeutics**, 14 (4): 336-340.

Jennane, N., Madani, N., Oulderrkhis, R., et al. (2011) Incidence of medication errors in a Moroccan medical intensive care unit. **International Archives of Medicine**, 4 (1) (32).

Johnson, J. A. and Bootman, J. (1995) Drug-related morbidity and mortality: A cost-of-illness model. **Archives of Internal Medicine**, 155 (18): 1949-1956.

Joint Commission (2014) Sentinel Event Alert, Issue 42: **Safely implementing health information and converging technologies**. December 11, 2008.

Joint Formulary Committee. **British National Formulary** [online]. BMJ Group and Pharmaceutical Press http://bng.org [Accessed 12 Sept 2014].

Joint Formulary Committee. **British National Formulary** [online]. BMJ Group and Pharmaceutical Press. www.bnf.org [Accessed 1 March 2012].

Jones, J. and Hunter, D. (1995) Consensus methods for medical and health services research. **BMJ**, 311 (7001): 376-380.

Kahneman, D. (2011) **Thinking, fast and slow**. Macmillan.

Kaplan, B. (2001) Evaluating informatics applications—some alternative approaches: theory, social interactionism and call for methodological pluralism. **International Journal of Medical Informatics**, 64 (1): 39-56.

Kaushal R, S. K. G. B. D. W. (2003) Effects of computerized physician order entry and clinical decision support systems on medication safety: A systematic review. **Archives of Internal Medicine**, 163 (12): 1409-1416.

Keller, K. B., Eggenberger, T. L., Belkowitz, J., et al. (2013) Implementing successful interprofessional communication opportunities in health care education: a qualitative analysis. **International Journal of Medical Education**, 4: 253-259.

Khalifa, M. and Zabani, I. (2016) Improving Utilization of Clinical Decision Support Systems by Reducing Alert Fatigue: Strategies and Recommendations. Studies in Health Technology & Informatics, 226: 51-54.

Kitzinger, J. (1994) The methodology of Focus Groups: the importance of interaction between research participants. Sociology of Health & Illness, 16 (1): 103-121.

Kitzinger, J. (1995) Qualitative Research: Introducing focus groups. **BMJ**, 311 (7000): 299-302.

Klopotowska, J. E., Kuiper, R., van, H. J. H., et al. (2010) On-ward participation of a hospital pharmacist in a Dutch intensive care unit reduces prescribing errors and related patient harm: an intervention study. **Critical Care** (London, England), 14 (5).

Koppel, R., Metlay, J., Cohen, A., et al. (2005) Role of computerised physician order entry systems in facilitating medication errors. **JAMA**, 293: 1197-1203.

Kozer, E., Scolnik, D., Macpherson, A., et al. (2002) Variables associated with medication errors in pediatric emergency medicine. **Pediatrics**, 110 (4): 737-742.

Kunac, D. L. and Reith, D. M. (2008) Preventable medication-related events in hospitalised children in New Zealand. **New Zealand Medical Journal**, 121 (1272): 17-32.

Langebrake, C. and Hilgarth, H. (2010) Clinical pharmacists' interventions in a German university hospital. **Pharmacy World & Science**, 32 (2): 194-199.

LaPointe, N. and G., J. J. (2003) Medication errors in hospitalized cardiovascular patients. **Archives of Internal Medicine**, 163 (12): 1461-1466.

Laroche, M. L., Charmes, J. P. and Merle, L. (2007) Potentially inappropriate medications in the elderly: a French consensus panel list. **European Journal of Clinical Pharmacology**, 63 (8): 725-731.

Laxmisan, A., Hakimzada, F., Sayan, O. R., et al. (2007) The multitasking clinician: Decision-making and cognitive demand during and after team handoffs in emergency care. **International Journal of Medical Informatics**, 76 (11–12): 801-811.

LeCompte, M. D. and Goetz, J. P. (1982) Problems of Reliability and Validity in Ethnographic Research. **Review of Educational Research**, 52 (1): 31-60.

Lederman, R. and Parkes, C. (2005) Systems Failure in Hospitals—Using Reason's Model to Predict Problems in a Prescribing Information System. **Journal of Medical Systems**, 29 (1): 33-43.

Lee, K. (2014) The proven ideal length of every Tweet, Facebook post and Headline online [online]. Fast Company. https://www.fastcompany.com/3028656/the-proven-ideal-length-of-every-tweet-facebook-post-and-headline-online [Accessed 19 Apr 2017].

Lee, L., Williams, R. and Sheikh, A. (2015) What does ePrescribing mean for patients? A Case Study of the Perspectives of Hospital Renal Patients. **Journal of innovation in health informatics**, 22 (4): 391-398.

Leonard, M., Graham, S. and Bonacum, D. (2004) The human factor: the critical importance of effective teamwork and communication in providing safe care. **Quality & Safety in Health Care**, 13 (Suppl 1): i85-i90.

Lesar, T. S., Briceland, L. and Stein, D. S. (1997a) Factors Related to Errors in Medication Prescribing. **JAMA**, 277 (4): 312-317.

Lesar, T. S., Lomaestro, B. M. and Pohl, H. (1997b) Medication-Prescribing Errors in a Teaching Hospital: A 9-Year Experience. **Archives of Internal Medicine**, 157 (14): 1569-1576.

Lewis, P. J., Ashcroft, D. M., Dornan, T., et al. (2014) Exploring the causes of junior doctors' prescribing mistakes: a qualitative study. **British Journal of Clinical Pharmacology**, 78 (2): 310-319.

Lewis, P. J., Dornan, T., Taylor, D., et al. (2009) Prevalence, incidence and nature of prescribing errors in hospital inpatients: a systematic review. **Drug Safety**, 32 (5): 379-389.

Liang, K. Y. and Zeger, S. L. (1986) Longitudinal data analysis using generalized linear models. **Biometrika**, 73 (1): 13-22.

Liddell, A., Adshead, S. and Burgess, E. (2008) **Technology in the NHS: Transforming the patient's experience of care** [online]. The King's Fund. https://www.kingsfund.org.uk/sites/files/kf/Technology-in-the-NHS-Transforming-patients-experience-of-care-Liddell-Adshead-and-Burgess-Kings-Fund-October-2008_0.pdf [Accessed 5 March 2017].

Lisby, M., Nielsen, L. P., Brock, B., et al. (2010) How are medication errors defined? A systematic literature review of definitions and characteristics. **International Journal for Quality in Health Care**, 22 (6): 507-518.

Liu, W., Manias, E. and Gerdtz, M. (2014) Medication communication through documentation in medical wards: knowledge and power relations. **Nursing Inquiry**, 21 (3): 246-258.

Liu, Y., Doucette, W. R. and Farris, K. B. (2010) Examining the development of pharmacist-physician collaboration over 3 months. **Research in Social & Administrative Pharmacy**, 6 (4): 324-333.

Luetsch, K. and Rowett, D. (2015) Interprofessional communication training: benefits to practicing pharmacists. **International Journal of Clinical Pharmacy**, 37 (5): 857-864.

Lunenburg, F. C. (2010) Communication: The process, barriers and improving effectiveness. **Schooling,** 1 (1): 1-11.

Luo, J., Wu, M., Gopukumar, D., et al. (2016) Big Data Application in Biomedical Research and Health Care: A Literature Review. **Biomedical Informatics Insights**, 8: 1-10.

Lyons, A. M., Sward, K. A., Deshmukh, V. G., et al. (2017) Impact of computerized provider order entry (CPOE) on length of stay and mortality. **Journal of the American Medical Informatics Association**, 24 (2): 303-309.

Madegowda, B., Hill, P. D. and Anderson, M. A. (2007) Medication errors in a rural hospital. **MEDSURG Nursing**, 16 (3): 175-180.

Malhotra, S., Cheriff, A. D., Gossey, J. T., et al. (2016) Effects of an e-Prescribing interface redesign on rates of generic drug prescribing: exploiting default options. **Journal of the American Medical Informatics Association**, 23 (5): 891-898.

Mannheimer, B., Ulfvarson, J., Eklöf, S., et al. (2006) Drug-related problems and pharmacotherapeutic advisory intervention at a medicine clinic. **European Journal of Clinical Pharmacology**, 62 (12): 1075-1081.

Marcin, J. P., Dharmar, M., Cho, M., et al. (2007) Medication errors among acutely ill and injured children treated in rural emergency departments. **Annals of Emergency Medicine**, 50 (4): 361-367, 367.e361-362.

Mark, G., Gudith, D. and Klocke, U. (2008) The cost of interrupted work: more speed and stress. **Proceedings of the SIGCHI Conference on Human Factors in Computing Systems**. Florence, Italy, ACM. 107-110.

Marvin, V., Kuo, S., Poots, A. J., et al. (2016) Applying quality improvement methods to address gaps in medicines reconciliation at transfers of care from an acute UK hospital. **BMJ** Open, 6 (6).

Mays, N. and Pope, C. (2000) Assessing quality in qualitative research. **BMJ**, 320 (7226): 50-52.

Mays N. and Pope C. (1995). Qualitative research: Observational methods in health care settings. BMJ,**British Medical Journal,** 15;311(6998):182.

McDonough, R. P., Doucette, W. R. (2001) Developing collaborative working relationships between pharmacists and physicians**. Journal of the American Pharmaceutical Association**, 41 (5): 682-692.

McLeod, M., Ahmed, Z., Barber, N., et al. (2014) A national survey of inpatient medication systems in English NHS hospitals. **BMC Health Services Research**, 14 (1): 93.

McMillan, S. S., King, M. and Tully, M. P. (2016) How to use the nominal group and Delphi techniques. **International Journal of Clinical Pharmacy**, 38: 655-662.

McMullen, C. K., Macey, T. A., Pope, J., et al. (2015) Effect of computerized prescriber order entry on pharmacy: Experience of one health system. **American Journal of Health-System Pharmacy**, 72 (2): 133-142.

Medicines and Healthcare products Regulatory Agency [online]. http://www.mhra.gov.uk [Accessed 1 March 2012].

Mohamed, I. N., Helms, P. J., Simpson, C. R., et al. (2011) Using primary care prescribing databases for pharmacovigilance. **British Journal of Clinical Pharmacology**, 71 (2): 244-249.

Morgan D L. (1998a) The focus group guide book. London: SAGE Publications Ltd.

Morgan, D. L. (1998b) **Planning Focus Groups**. Thousand Oaks, CA: SAGE Publications Ltd.

Morrow, G., Burford, B., Rothwell, C., et al. (2011) **Professionalism in healthcare professionals**. Report to the Health and Care Professions Council London: HCPC.

Mozaffar, H., Cresswell, K. M., Williams, R., et al. (2017) Exploring the roots of unintended safety threats associated with the introduction of hospital ePrescribing systems and candidate avoidance and/or mitigation strategies: a qualitative study. **BMJ Quality & Safety**. Publised online first: 7 February 2017

Murdoch, T. B. and Detsky, A. S. (2013) THe inevitable application of big data to health care. **JAMA**, 309 (13): 1351-1352.

Murphy, D. R., Reis, B., Sittig, D. F., et al. (2012) Notifications Received by Primary Care Practitioners in Electronic Health Records: A Taxonomy and Time Analysis. **The American Journal of Medicine**, 125 (2): 209.e201-209.e207.

National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP) (2012) [online]. http://www.nccmerp.org/aboutMedErrors.html [Accessed 8th March 2012].

National Coordinating Council for Medication Error Reporting Prevention (1998) **NCC MERP Taxonomy of Medication Errors** [online]. http://www.nccmerp.org/taxonomy-medication-errors-now-available [Accessed 22 Feb 2012].

National Information Board (2014) **Personalised Health and Care 2020. Using Data and Technology to Transform Outcomes for Patients and Citizens: A framework for action** [online]. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/384650/NIB_Report.pdf [Accessed 19 Feb 2017].

National Institute for Health and Care Excellence (2013) **Falls in older people: assessing risk and prevention** NICE Guideline (CG161) [online]. https://www.nice.org.uk/guidance/cg161 [Accessed 01 May 2017].

National Institute for Health and Care Excellence (2015) **Medicines optimisation: the safe and effective use of medicines to enable the best possible outcomes**. NICE guideline (CG5). [online]. https://www.nice.org.uk/guidance/ng5 [Accessed 29 April 2017].

National Patient Safety Agency [online]. www.npsa.nhs.uk [Accessed 1 March 2012].

National Patient Safety Agency (2008) A risk matrix for risk managers [online]. http://www.nrls.npsa.nhs.uk/EasySiteWeb/getresource.axd?AssetID=60149 [Accessed 2 March 2012]

Nebeker, J. R., Hoffman, J. M., Weir, C. R., et al. (2005) High rates of adverse drug events in a highly computerized hospital. **Archives of Internal Medicine**, 165 (10): 1111-1116.

Nguyen, C., McElroy, L. M., Abecassis, M. M., et al. (2015) The use of technology for urgent clinician to clinician communications: A systematic review of the literature. **International Journal of Medical Informatics**, 84 (2): 101-110.

NHS Connecting for Health (2009) **Electronic prescribing in hospitals: Challenges and lessons learned** [online]. http://www.connectingforhealth.nhs.uk/systemsandservices/eprescribing/challenges/Final_report.pdf [Accessed 7 May 2012].

NHS England (2013) Safer Hospitals, **Safer Wards: achieving an integrated digital care record** [online]. http://www.england.nhs.uk/wp-content/uploads/2013/07/safer-hosp-safer-wards.pdf [Accessed 13 August 2016].

NHS England (2014a) **NHS Five Year Forward View** [online]. http://www.england.nhs.uk/wp-content/uploads/2014/10/5yfv-web.pdf [Accessed 12 Mar 2017].

NHS England (2014b) **The Integrated Digital Care Fund** [online]. http://www.england.nhs.uk/wp-content/uploads/2014/05/idcr.pdf [Accessed 4 April 2017].

NHS England (2015) **Clinical Digital Maturity Index** [online]. https://www.england.nhs.uk/digitaltechnology/info-revolution/maturity-index/ [Accessed 22 Nov 2016].

NHS England (2016) **Seven Day Services Clinical Standards** [online]. https://www.england.nhs.uk/ourwork/qual-clin-lead/seven-day-hospital-services/resources/ [Accessed 3 May 2017].

NHS England (2017) **Patient safety incident reporting continues to improve** [online]. https://www.england.nhs.uk/2015/09/patient-safety-reporting/ [Accessed 5 March 2017].

Niazkhani, Z., Pirnejad, H., Berg, M., et al. (2009) The impact of computerized provider order entry systems on inpatient clinical workflow: a literature review. **Journal of the American Medical Informatics Association**, 16 (4): 539-549.

Niazkhani, Z., Pirnejad, H., De, A., et al. (2008) Evaluating inter-professional work support by a Computerized Physician Order Entry (CPOE) system. S**tudies in Health Technology and Informatics**, 136: 321-326.

Niazkhani, Z., Pirnejad, H., van der Sijs, H., et al. (2010) Computerized provider order entry system--does it support the inter-professional medication process? Lessons from a Dutch academic hospital. **Methods of Information in Medicine**, 49 (1): 20-27.

Nightingale, P. G., Adu, D., Richards, N. T., et al. (2000) Implementation of rules based computerised bedside prescribing and administration: intervention study. **BMJ**, 320 (7237): 750-753.

NSW Therapeutic Advisory Group (2007) **Indicators for Quality Use of Medicines in Australian Hospitals** [online]. http://www.ciap.health.nsw.gov.au/nswtag/reviews/indicators.html [Accessed 3 January 2013].

Nuckols, T. K., Smith-Spangler, C., Morton, S. C., et al. (2014) The effectiveness of computerized order entry at reducing preventable adverse drug events and medication errors in hospital settings: a systematic review and meta-analysis. **Systematic Reviews**, 3: 56-56.

Office of the Chief Pharmaceutical Officer, M. D. (2016) **Transformation of seven day clinical pharmacy services in acute hospitals.** London. [online]. https://www.england.nhs.uk/wp-content/uploads/2016/09/7ds-clinical-pharmacy-acute-hosp.pdf [Accessed Sept 2016].

Office of the National Coordinator for Health Information Technology (2014) Safety Assurance Factors for EHR Resilience Guides: Clinician Communication [online]. https://www.healthit.gov/safer/safer-guides [Accessed 22 Apr 2017].

Parker, J. and Coiera, E. (2000) Improving Clinical Communication: A View from Psychology. **Journal of the American Medical Informatics Association**, 7 (5): 453-461.

Parthasarathi, G., Ramesh, M., Kumar, J. K., et al. (2003) Assessment of Drug-Related Problems and Clinical Pharmacists' Interventions in an Indian Teaching Hospital. **Journal of Pharmacy Practice and Research,** 33 (4): 272-274.

Pearson, S. A., Moxey, A., Robertson, J., et al. (2009) Do computerised clinical decision support systems for prescribing change practice? A systematic review of the literature (1990-2007). **BMC Health Services Research**, 9: 154.

Pedersen, C. A., Schneider, P. J. and Scheckelhoff, D. J. (2015) ASHP national survey of pharmacy practice in hospital settings: Dispensing and administration—2014. **American Journal of Health-System Pharmacy**, 72 (13): 1119-1137.

Perraudin, C., Brion, F., Bourdon, O., et al. (2011) The future of pharmaceutical care in France: a survey of final-year pharmacy students' opinions. **BMC Clinical Pharmacology**, 11 (1): 6.

Pham, J. C., Story, J. L., Hicks, R. W., et al. (2011) National study on the frequency, types, causes and consequences of voluntarily reported emergency department medication errors. **The Journal of Emergency Medicine**, 40 (5): 485-492.

Phansalkar, S., Desai, A. A., Bell, D., et al. (2012) High-priority drug–drug interactions for use in electronic health records. **Journal of the American Medical Informatics Association**, 19(5): 735-743.

Phansalkar, S., Edworthy, J., Hellier, E., et al. (2010) A review of human factors principles for the design and implementation of medication safety alerts in clinical information systems. **Journal of the American Medical Informatics Association**, 17 (5): 493-501.

Pharmaceutical Care Network Europe (2012) [online]. http://www.pcne.org/sig/drp/drug-related-problems.php [Accessed 8 March 2012].

Pharmaceutical Care Network Europe Foundation (2010) **The PCNE Classification V 6.2** [online]. http://www.pcne.org/upload/files/11_PCNE_classification_V6-2.pdf [Accessed 8 March 2012].

Picone, D. M., Titler, M. G., Dochterman, J., et al. (2008) Predictors of medication errors among elderly hospitalized patients. **American Journal of Medical Quality**, 23 (2): 115-127.

Pirnejad, H., Niazkhani, Z., van der Sijs, H., et al. (2008) Impact of a computerized physician order entry system on nurse-physician collaboration in the medication process. *International Journal of Medical Informatics*, 77 (11): 735-744.

Pirnejad, H., Niazkhani, Z., van der Sijs, H., et al. (2009) Evaluation of the impact of a CPOE system on nurse-physician communication--a mixed method study. **Methods Inf Med**, 48 (4): 350-360.

Plsek, P. E. and Greenhalgh, T. (2001) The challenge of complexity in health care. **BMJ**, 323 (7313): 625-628.

Pollock, N. and Williams, R. (2010) e-Infrastructures: How Do We Know and Understand Them? Strategic Ethnography and the Biography of Artefacts. **Computer Supported Cooperative** Work (CSCW), 19 (6): 521-556.

Pontefract, S. K., Hodson, J., Marriott, J. F., et al. (2016) Pharmacist-Physician Communications in a Highly Computerised Hospital: Sign-Off and Action of Electronic Review Messages. **PLoS ONE**, 11 (8): e0160075.

Pope, C. (2005) Conducting ethnography in medical settings. **Medical Education**, 39 (12): 1180-1187.

Popovici, I., Morita, P. P., Doran, D., et al. (2015) Technological aspects of hospital communication challenges: an observational study. **International Journal for Quality in Health Care**, 27 (3): 183-188.

PricewaterhouseCoopers LLP (2013) A **review of the potential benefits from the better use of information and technology in Health and Social Care** [online]. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/217012/DoH-Review-of-Information-and-Technology-Use-Final-Report-V2.pdf [Accessed 4 Nov 2015].

Quélennec, B., Beretz, L., Paya, D., et al. (2013) Potential clinical impact of medication discrepancies at hospital admission. **European Journal of Internal Medicine**, 24 (6): 530-535.

Radley, D. C., Wasserman, M. R., Olsho, L. E. W., et al. (2013) Reduction in medication errors in hospitals due to adoption of computerized provider order entry systems. **Journal of the American Medical Informatics Association,** 2013: 470-476.

Raghupathi, W. and Raghupathi, V. (2014) Big data analytics in healthcare: promise and potential. **Health Information Science and Systems**, 2 (1): 1-10.

Ranji, S. R., Rennke, S. and Wachter, R. M. (2014) Computerised provider order entry combined with clinical decision support systems to improve medication safety: a narrative review. **BMJ Quality & Safety**, pp.bmjqs-2013.

Reason, J. (2004) Beyond the organisational accident: the need for “error wisdom” on the frontline. **Quality & Safety in Health Care**, 13 (suppl 2): ii28-ii33.

Reason, J. T. (1990) **Human Error**. Cambridge: Cambridge University Press.

Reddy, M. C., Dourish, P. and Pratt, W. (2001) "Coordinating Heterogeneous Work: Information and Representation in Medical Care." In Prinz, W., Jarke, M., Rogers, Y., Schmidt, K. and Wulf, V. (eds.) ECSCW 2001: **Proceedings of the Seventh European Conference on Computer Supported Cooperative Work** 16–20 September 2001, Bonn, Germany. Dordrecht: Springer Netherlands. pp.239-258.

Reddy, M. C., McDonald, D. W., Pratt, W., et al. (2005) Technology, work and information flows: Lessons from the implementation of a wireless alert pager system. **Journal of Biomedical Informatics**, 38 (3): 229-238.

Redwood, S., Rajakumar, A., Hodson, J., et al. (2011) Does the implementation of an electronic prescribing system create unintended medication errors? A study of the sociotechnical context through the analysis of reported medication incidents. **BMC Medical Informatics and Decision Making**, 11 (29).

Reeves, S., Kuper, A. and Hodges, B. D. (2008) Qualitative research methodologies: ethnography. **BMJ**, 337 (a1020).

Riedmann, D., Jung, M., Hackl, W. O., et al. (2011) Development of a context model to prioritize drug safety alerts in CPOE systems. **BMC Medical Informatics & Decision Making**, 11: 35.

Roethlisberger FJ, Dickson WJ. Management and the Worker. Cambridge, MA: Harvard University Press; 1961.

Roshanov, P. S., Fernandes, N., Wilczynski, J. M., et al. (2013) Features of effective computerised clinical decision support systems: meta-regression of 162 randomised trials. **BMJ**, 346 (f657).

Ross, L. M., Wallace, J. and Paton, J. Y. (2000) Medication errors in a paediatric teaching hospital in the UK: five years operational experience. **Archives of Disease in Childhood**, 83 (6): 492-497.

Ross, S., Hamilton, L., Ryan, C., et al. (2012) Who makes prescribing decisions in hospital inpatients? An observational study. **Postgraduate Medical Journal**, 88 (1043): 507-510.

Ross, S., Ryan, C., Duncan, E. M., et al. (2013) Perceived causes of prescribing errors by junior doctors in hospital inpatients: a study from the PROTECT programme. **BMJ Quality & Safety**, 22 (2): 97-102.

Royal Pharmaceutical Society (2012) Professional Standards for Hospital Pharmacy Services: Optimising patient outcomes from medicines [online]. http://www.rpharms.com/hospital-pharmacy-services/professional-standards.asp [Accessed 24 August 2012].

Royal Pharmaceutical Society (2014) Professional Standards for Hospital Pharmacy Services [online]. http://www.rpharms.com/hospital-pharmacy-services/professional-standards.asp [Accessed 4 April 2017].

Royal Pharmaceutical Society (2016) **Medicines, Ethics and Practice: The professional guide for pharmacists**. Ed. 40. London.

Ryan, C., Ross, S., Davey, P., et al. (2013) Junior doctors' perceptions of their self-efficacy in prescribing, their prescribing errors and the possible causes of errors. **British Journal of Clinical Pharmacology**, 76 (6): 980-987.

Saedder, E., Brock, B., Nielsen, L., et al. (2014) Identifying high-risk medication: a systematic literature review. **European Journal of Clinical Pharmacology**, 70 (6): 637-645.

Saldana, J. (2013) **The Coding Manual for Qualitative Researchers 2nd ed**. London: Sage. pp.70-71.

Saleem, J. J., Russ, A. L., Neddo, A., et al. (2011) Paper persistence, workarounds and communication breakdowns in computerized consultation management. **International Journal of Medical Informatics**, 80 (7): 466-479.

Schaefer, M. (2002) Discussing basic principles for a coding system of drug-related problems: the case of PI-Doc. **Pharmacy World & Science**, 24 (4): 120-127.

Schedlbauer, A., Prasad, V., Mulvaney, C., et al. (2009) What Evidence Supports the Use of Computerized Alerts and Prompts to Improve Clinicians' Prescribing Behavior? **Journal of the American Medical Informatics Association**, 16 (4): 531-538.

Schmidt, K. (2002) The Problem with `Awareness': Introductory Remarks on Awareness in CSCW. **Computer Supported Cooperative Work**, 11 (3-4): 285-298.

Seidling, H. M., Phansalkar, S., Seger, D. L., et al. (2011) Factors influencing alert acceptance: a novel approach for predicting the success of clinical decision support. **Journal of the American Medical Informatics Association**, 18 (4): 479-484.

Shamliyan, T. A., Duval, S., Du, J., et al. (2008) Just what the doctor ordered. Review of the evidence of the impact of computerized physician order entry system on medication errors. **Health Services Research**, 43 (1): 32-53.

Shawahna, R. and Rahman, N. U. (2009) Defining prescribing errors in general practice for the hospitals in Pakistan. **Pakistan Armed Forces Medical Journal**, (2).

Shawahna, R., Rahman, N. U., Ahmad, M., et al. (2011) Electronic prescribing reduces prescribing error in public hospitals. **Journal of Clinical Nursing**, 20 (21-22): 3233-3245.

Shojania, K. G., Jennings, A., Mayhew, A., et al. (2009) **The effects of on-screen, point of care computer reminders on processes and outcomes of care** (Review). Cochrane Database of Systematic Reviews, 3: CD001096.

Shortliffe, E. H. (1987) Computer programs to support clinical decision making. **JAMA**, 258 (1): 61-66.

Silverman, D., ed, (2016) **Qualitative Research**. SAGE Publciations Ltd.

Singh, H., Mani, S., Espadas, D., et al. (2009) Prescription errors and outcomes related to inconsistent information transmitted through computerized order entry: A prospective study. **Archives of Internal Medicine**, 169 (10): 982-989.

Sittig D. F. and Singh H. (2010). A new sociotechnical model for studying health information technology in complex adaptive healthcare systems. **Quality and Safety in Health Care**, 19(Suppl 3):i68-74.

Slight, S. P., Berner, E. S., Galanter, W., et al. (2015) Meaningful Use of Electronic Health Records: Experiences From the Field and Future Opportunities. **JMIR Medical Informatics**, 3 (3): e30.

Spina, J. R., Glassman, P. A., Simon, B., et al. (2011) Potential safety gaps in order entry and automated drug alerts: A nationwide survey of VA physician self-reported practices with computerized order entry. **Medical Care**, 49 (10): 904-910.

Sturmberg, J. P., O'Halloran, D. M. and Martin, C. M. (2012) Understanding health system reform – a complex adaptive systems perspective. **Journal of Evaluation in Clinical Practice**, 18 (1): 202-208.

Tan, C., Sun, L. and Liu, K. (2015) **Big Data Architecture for Pervasive Healthcare: A Literature Review**. ECIS 2015 Completed Research Papers Paper 177.

Taylor, S. P., Ledford, R., Palmer, V., et al. (2014) We need to talk: an observational study of the impact of electronic medical record implementation on hospital communication. **BMJ Quality & Safety**, 23(7): 584-588

The Information Centre (Health Care) (2012) **The Prescribing Toolkit** [online]. http://www.ic.nhs.uk/prescribing/measures [Accessed 22 August 2012].

The Joint Commission on Accreditation of Healthcare Organizations (2015) **Sentinel Events Statistics** [online]. http://www.jointcommission.org/sentinel_event.aspx [Accessed 20 Mar 2017].

The NHS Health and Social Care Information Centre (2012) **Prescriptions Dispensed in the Community**: **England, Statistics for 2001 to 2011**. [online]. http://content.digital.nhs.uk/catalogue/PUB06941/pres-disp-com-eng-2001-11-rep.pdf Accessed Sept 2012].

Thomas, S. K. and Coleman, J. J. (2012) The impact of computerised physician order entry with integrated clinical decision support on pharmacist–physician communication in the hospital setting: a systematic review of the literature**. European Journal of Hospital Pharmacy: Science and Practice**, 19 (3): 349-354.

Thomas, S. K., McDowell, S. E., Hodson, J., et al. (2013) Developing consensus on hospital prescribing indicators of potential harms amenable to decision support. **British Journal of Clinical Pharmacology**, 76 (5): 797-809.

Tully, M., Ashcroft, D., Dornan, T., et al. (2009) The Causes of and Factors Associated with Prescribing Errors in Hospital Inpatients. **Drug Safety**, 32 (10): 819-836.

Tully, M. P. and Buchan, I. E. (2009) Prescribing errors during hospital inpatient care: factors influencing identification by pharmacists. **Pharmacy World & Science**, 31 (6): 682-688.

U.S. National Library of Medicine. Medical subject headings (MeSH) [online]. https://www.nlm.nih.gov/pubs/factsheets/mesh.html [Accessed November 2011).

Urban, R., Armitage, G., Morgan, J., et al. (2014) Custom and practice: A multi-center study of medicines reconciliation following admission in four acute hospitals in the UK. **Research in Social and Administrative Pharmacy**, 10 (2): 355-368.

van den Bemt, P. M., Egberts, T. C. and Brouwers, J. R. (2000) Drug-related problems in hospitalised patients. **Drug Safety**, 22 (4): 321-333.

van der Linden CM, Jansen PA, van Marum RJ., et al. (2012). An electronic system to document reasons for medication discontinuation and to flag unwanted represcriptions in geriatric patients. **Drugs & Aging**, 1;29(12):957-62.

van der Sijs, H., Aarts, J., van Gelder, T., et al. (2008a) Turning off frequently overridden drug alerts: limited opportunities for doing it safely. **Journal of the American Medical Informatics Association**, 15 (4): 439-448.

van der Sijs, H., Aarts, J., van Gelder, T., et al. (2008b) Turning off frequently overridden drug alerts: limited opportunities for doing it safely**. Journal of the American Medical Informatics Association**, 15 (4): 439-448.

van der Sijs, H., Aarts, J., Vulto, A., et al. (2006) Overriding of Drug Safety Alerts in Computerized Physician Order Entry**. Journal of the American Medical Informatics Association**, 13 (2): 138-147.

van der Sijs, H., van Gelder, T., Vulto, A., et al. (2010) Understanding handling of drug safety alerts: a simulation study. **International Journal of Medical Informatics**, 79 (5): 361-369.

van Mil, F. (2005) Drug-related problems: a cornerstone for pharmaceutical care. **Journal of the Malta College of Pharmacy Practice**, (10): 5-8.

van Mil, J. F., Westerlund, L. T., Hersberger, K. E., et al. (2004) Drug-Related Problem Classification Systems. **The Annals of Pharmacotherapy**, 38 (5): 859-867.

Varpio, L., Day, K., Elliot-Miller, P., et al. (2015a) The impact of adopting EHRs: how losing connectivity affects clinical reasoning. **Medical Education**, 49 (5): 476-486.

Varpio, L., Rashotte, J., Day, K., et al. (2015b) The EHR and building the patient's story: A qualitative investigation of how EHR use obstructs a vital clinical activity. **International Journal of Medical Informatics**, 84 (12): 1019-1028.

Venkatesh, V., Brown, S. A. and Bala, H. (2013) Bridging the qualitative-quantitative divide: guidelines for conducting mixed methods research in information systems. **MIS Quarterly**, 37 (1): 21-54.

Vrca, V. B., Becirevic-Lacan, M., Bozikov, V., et al. (2005) Prescribing medication errors in hospitalised patients: A prospective study. **Acta Pharmaceutica**, 55 (2): 157-167.

Wachter, R. M. (2016) Making IT Work: **Harnessing the power of health information technology to improve care in England** [online]. Department of Health, London. https://www.gov.uk/government/publications/using-information-technology-to-improve-the-nhs [Accessed 14 Apr 2017].

Walker, J., Pan, E., Johnston, D., et al. (2005) The Value Of Health Care Information Exchange And Interoperability. **Health Affairs**, Jan-Jun; Suppl Web Exclusives:W5-10-W5-1.

Westbrook, J. I., Baysari, M. T., Li, L., et al. (2013) The safety of electronic prescribing: manifestations, mechanisms and rates of system-related errors associated with two commercial systems in hospitals. **Journal of the American Medical Informatics Association**, 20 (6): 1159-1167.

Westbrook, J. I., Coiera, E., Dunsmuir, W. T. M., et al. (2010) The impact of interruptions on clinical task completion. **Quality and Safety in Health Care**, 19 (4): 284-289.

Westbrook, J. I., Reckmann, M., Li, L., et al. (2012) Effects of two commercial electronic prescribing systems on prescribing error rates in hospital in-patients: a before and after study. **PLoS Med**, 9 (1): e1001164.

Wilson, D. G., McArtney, R. G., Newcombe, R. G., et al. (1998) Medication errors in paediatric practice: insights from a continuous quality improvement approach. **European Journal of Pediatrics**, 157 (9): 769-774.

Wong, H. J., Bierbrier, R., Ma, P., et al. (2017) An analysis of messages sent between nurses and physicians in deteriorating internal medicine patients to help identify issues in failures to rescue. **International Journal of Medical Informatics**, 100: 9-15.

World Health Organization (2009) **Conceptual framework for the international classification for patient safety** (version 1.1) [online]. http://www.who.int/patientsafety/taxonomy/icps_full_report.pdf [Accessed 16 April 2012].

World Health Organization (2012) **WHO Draft Guidelines for Adverse Event Reporting and Learning Systems** [online]. http://www.who.int/patientsafety/implementation/reporting_and_learning/en/index.html [Accessed 16 March 2012].

World Health Organization (2014) **Reporting and learning systems for medication errors: the role of pharmacovigilance centres** [online]. http://apps.who.int/iris/bitstream/10665/137036/1/9789241507943_eng.pdf?ua=1 [Accessed 24 March 2017].

World Health Organization (2017) **Medication Without Harm: WHO's Third Global Patient Safety Challenge** [online]. http://www.who.int/patientsafety/medication-safety/en/ [Accessed 29 April 2017].

Wu, R. C., Lo, V., Morra, D., et al. (2013) The intended and unintended consequences of communication systems on general internal medicine inpatient care delivery: a prospective observational case study of five teaching hospitals. **Journal of the American Medical Informatics Association**, 20 (4): 766-777.

Wu, R. C., Tran, K., Lo, V., et al. (2012) Effects of clinical communication interventions in hospitals: A systematic review of information and communication technology adoptions for improved communication between clinicians. **International Journal of Medical Informatics**, 81 (11): 723-732.

Zinn.C (1995) 14,000 preventable deaths in Australian hospitals. **BMJ**, 310: 1487.

Zoni, A. C., Durán García, M. E., Jiménez Muñoz, A. B., et al. (2012) The impact of medication reconciliation program at admission in an internal medicine department. **European Journal of Internal Medicine**, 23 (8): 696-700.

Appendix 1 – Characteristics of studies identified in the narrative review

Author, Year	Country	Study type	Study Aim	Medication process	Terminology used	Source of classification scheme
Lesar *et al.,* 1997b	US	Prospective analysis of medication-prescribing errors	To report a programme for detecting, recording and evaluating medication-prescribing errors	Paper-based	Medication-prescribing error	Not defined
Wilson *et al.,* 1998)	UK	Prospective review of adverse incident reports	To investigate the incidence and outcome of medication errors	Paper-based	Medication errors	Based on (American Society of Hospital Pharmacists (ASHP), 1993)
Ross *et al*., 2000	UK	Retrospective review of medication errors	To investigate the incidence and types of medication errors and the impact of error prevention programmes	Paper-based	Medication errors	Not defined
Fijn *et al.,* 2002	Netherlands	Retrospective case-control study comparing prescriptions with and without errors	To explore a method to assess predictors of prescribing error	Paper-based	Prescribing errors	Based on other published studies
(Kozer *et al*., 2002)	Canada	Retrospective review of inpatient drug chart	To investigate the incidence and type of medication errors and determine factors associated with risk of errors	Paper-based	Medication errors	Classified according to the system described by (Lesar *et al.*, 1997a)
LaPointe & G., 2003	US	Prospective review of medication orders	To investigate the type of error, stage in the process and professionals involved	Paper-based	Medication errors	The ADE Prevention Study Group
Parthasarathi *et al*., 2003	India	Prospective review of inpatient drug charts	Assess the acceptance of drug-related interventions	Paper-based	Drug-related problems	Not defined
Bobb *et al.,* 2004)	US	Prospective analysis of medication orders	To investigate prescribing errors averted by pharmacists and the likely impact of CPOE	Paper-based	Prescribing errors	Not defined
Chen *et al.,* 2004)	Taiwan	Retrospective review of incident forms	To investigate the incidence and type of medication errors	CPOE	Medication errors	Not defined
Nebeker *et al*., 2005	Canada	Prospective review of case notes	To investigate the frequency and type of ADEs after CPOE	CPOE	ADEs	NCC MERP

Author, Year	Country	Study type	Study Aim	Prescribing process	Definition used	Source of classification scheme
Vrca *et al.,* 2005)	Croatia	Prospective review of inpatient drug charts	To determine the incidence and type of prescribing medication error	Paper-based	Prescribing medication errors	Not defined
Ashcroft & Cooke, 2006	UK	Retrospective analysis of medication-related incidents reports	Frequency and type of incidents in the medication process and the reporting profession	Paper-based	Medication errors	Not defined
Barber *et al.,* 2006)	UK	Prospective evaluation of medication orders	To prospectively evaluate the impact of a closed-loop CPOE system and automated dispensing system	CPOE	Medication error	Based on a published study by (Dean *et al.*, 2002b)
Colpaert *et al.,* 2006)	Belgium	Prospective review of inpatient prescriptions	To determine the impact of CPOE on the incidence and severity of medication prescription errors	Paper-based and CPOE	Medication prescription errors	NCC MERP Taxonomy of Medication Errors
Devine *et al.,* 2007)	US	Retrospective review of prescriptions	To characterise the epidemiology of prescribing errors pre-/post-implementation of CPOE	Paper-based	Medication error	Based on published studies
Jayawardena *et al.,* 2007	US	Retrospective study of electronic prescriptions	To investigate the impact of a CPOE system on the rate and type of prescription errors	CPOE	Prescription errors	Not defined
Marcin *et al.,* 2007)	US	Retrospective review of case notes	To identify the incidence, nature and outcomes of medication errors	Paper-based	Medication errors	Modification of NCC MERP Taxonomy of Medication Errors
Madegowda et al., 2007	Morocco	Retrospective review of medication error reports	To investigate the number, type and severity of errors reported by three nursing shifts	Paper-based	Medication errors	Self-developed
Engum & Breckler, 2008	US	Retrospective review of voluntary reports of medication error	To review the number and type of medication errors across specialities	Paper-based	Medication errors	Not defined
Picone *et al.,* 2008)	US	Retrospective review of voluntary incident reports	To describe medication errors and the factors predictive of errors	Paper-based	Medication errors	Not defined
Kunac & Reith, 2008)	New Zealand	Prospective observational study of inpatient drug charts, incident reports and attendance at MDTs	To evaluate the incidence and preventability of medication-related events	Paper-based	Medication-related events	NCC MERP Taxonomy of Medication Errors

Author, Year	Country	Study type	Study Aim	Prescribing process	Definition used	Source of classification scheme
Pham *et al.,* 2011	US	Cross-sectional study of medication errors reports from the emergency departments	To investigate the frequency, types, causes and outcomes of medication errors	Paper-based and CPOE	Medication errors	Modification of the NCC MERP Taxonomy of Medication Errors
Dornan *et al.,* 2009b	UK	Prospective chart review	To explore the causes of prescribing errors made by foundation trainees	Paper-based	Prescribing errors	Not defined
Ghaleb *et al.,* 2010	UK	Prospective review of inpatient drug charts	To determine the incidence and nature of prescribing and medication administration errors	Paper-based	Prescribing errors	Based on a previous study by the same author (Ghaleb et al., 2005)
Klopotowska *et al.,* 2010	Netherlands	Prospective study of electronic prescriptions	To investigate the impact of a hospital pharmacist on prescribing errors and related patient harm	CPOE	Prescribing errors and related ADEs	Not defined
Al-Jeraisy *et al.,* 2011	Saudi Arabia	Retrospective review of inpatient drug charts and patient notes	To investigate the incidence and types of medication prescribing errors and risk factors	Paper-based	Medication prescribing errors	Based on published studies
Franklin *et al.,* 2011	UK	Prospective study of prescribing errors identified by ward pharmacists	To compare the prevalence and causes of prescribing errors in three hospitals	Paper-based	Prescribing errors	Not defined
Hartel *et al.,* 2011	Switzerland	Retrospective review of inpatient drug charts	To investigate the frequency and type of medication errors in the medication documentation process	Paper-based	Medication errors	Based on a published study by (Barker et al., 2002)
Jennane *et al.,* 2011	Morocco	Prospective review of inpatient drug charts	To determine incidence, type and outcomes of medication errors	Paper-based	Medication errors	Not defined
Shawahna *et al.*, 2011	Pakistan	Prospective review of inpatient drug charts	To investigate the incidence of prescribing errors pre-/post-implementation of CPOE	Paper-based and CPOE	Prescribing errors	Based on a published study by (Shawahna & Rahman, 2009)
Westbrook et al., 2012	Australia	Prospective analysis of medication orders	To investigate the effectiveness of two CPOE systems in reducing prescribing error and their propensity for new error types	Paper-based and CPOE	Prescribing errors	Not defined

ADE; Adverse drug events

Appendix 2 – Participant Information Leaflet for the eDelphi study

Identifying and establishing consensus on prescribing safety indicators in secondary care: an eDelphi study

Background

Prescribing safety indicators have been well researched in primary care. However, the development of such indicators in the secondary care setting is limited. We wish to establish a consensus on the prescribing indicators judged by experts to have a significant risk of translating into actual patient harm in UK secondary care. These indicators will be used to evaluate whether the introduction of electronic prescribing (ePrescribing) systems results in a reduction in clinically important errors.

This research is part of a larger mixed methods project funded by the National Institute for Health Research to investigate the implementation, adoption and effectiveness of ePrescribing systems in English hospitals.

The eDelphi process

We will use an electronic Delphi (eDelphi) technique to gain consensus on the opinions of experts through a series of questionnaires. The technique has been used previously in healthcare research to establish consensus. We have derived an initial list of 90 prescribing safety indicators through literature searching and clinical experience for consideration by the panel of experts.

The eDelphi will be undertaken by email in three rounds:

Round 1 A list of indicators will be sent out to participants, who will be asked to suggest critical indicators that they think are missing.

Round 2 Responses from Round 1 will be analysed and collated into a second, larger list of indicators, which will be sent by email to participants. This spreadsheet will have a scoring functionality, where participants will score the likelihood of the error occurring and the seriousness of the error should it occur using a 5-point Likert scale.

Round 3 Participants will receive a second spreadsheet containing their initial score and the median score for each indicator. Participants will be asked if they want to change their score in response to the median value. A comments section will allow respondents to justify/comment on their scoring decision.

Participants will be given 7–10 working days to reply during each round.

Appendix 3 – High or extreme risk prescribing indicators, with median scores from the eDelphi shown for the severity and likelihood, with a calculated risk score

Prescribing Safety Indicator Title	Group	Error type	Median severity score	Median likelihood score	Risk score	Percentage agreement
Low molecular weight heparin prescribed without the patient's weight being used to calculate the treatment dose *(Risk of subtherapeutic or supratherapeutic dosing)*	Cardiovascular	Dosing	3	4	3	95%
Low molecular weight heparin prescribed at a dose exceeding the maximum as stated in the product literature *(Risk of bleeding increased)*	Cardiovascular	Dosing	4	3	3	90%
Digoxin prescribed at a dose >125 micrograms daily to a patient with renal impairment *(Increased risk of digoxin toxicity)*	Cardiovascular	Dosing	3	3	3	95%
Digoxin prescribed at a dose of >125 micrograms daily to a patient with heart failure who is in sinus rhythm *(Increased risk of digoxin toxicity)*	Cardiovascular	Dosing	3	3	3	95%
Amiodarone prescribed to a patient with abnormal thyroid function tests *(Increased risk of thyroid disorders)*	Cardiovascular	Clinical contraindication	3	3	3	80%
Non-cardioselective beta-adrenoceptor blocking drug prescribed to a patient with COPD *(Increased risk of bronchospasm)*	Cardiovascular	Clinical contraindication	3	3	3	85%
ACE inhibitor or angiotensin-II receptor antagonist prescribed to a patient with a potassium level $\geq$5.0 mmol/litre *(Can cause or exacerbate hyperkalaemia)*	Cardiovascular	Clinical contraindication	3	3	3	80%
Verapamil prescribed to a patient with NYHA Class III or IV heart failure *(Risk of precipitating heart failure, exacerbating conduction disorders and causing significant deterioration)*	Cardiovascular	Clinical contraindication	4	3	3	95%
Low molecular weight heparin prescribed to a patient with renal impairment without dose adjustment *(Increased risk of bleeding)*	Cardiovascular	Dosing	3	4	3	100%

Warfarin prescribed to a patient with a concurrent bleeding disorder *(Increased risk of bleeding)*	Cardiovascular	Clinical contraindication	4	2	3	100%
Aspirin prescribed to a patient with a past medical history of peptic ulcer disease without antisecretory drugs or mucosal protectants *(Increased risk of peptic ulceration and risk of bleeding)*	Cardiovascular	Clinical contraindication	4	3	3	95%
Antiplatelet prescribed to a patient with a concurrent bleeding disorder *(Increased risk of bleeding)*	Cardiovascular	Clinical contraindication	4	3	3	100%
Digoxin prescribed concomitantly with a diuretic *(Risk of hypokalaemia and subsequent digoxin toxicity)*	Cardiovascular	Drug-drug interaction	3	4	3	100%
Statin prescribed concomitantly with a macrolide antibiotic *(Increased risk of myopathy)*	Cardiovascular	Drug-drug interaction	3	4	3	95%
Potassium-sparing diuretic (excluding aldosterone antagonists) prescribed to a patient also receiving an ACE inhibitor or angiotensin-II receptor antagonist *(Increased risk of severe hyperkalaemia)*	Cardiovascular	Drug-drug interaction	3	3	3	90%
Amiodarone prescribed concomitantly with simvastatin 40 mg or above *(Increased risk of myopathy)*	Cardiovascular	Drug-drug interaction	3	3	3	85%
Verapamil prescribed to a patient concomitantly a with beta-adrenoceptor blocking drug *(Increased risk of adverse cardiovascular effects)*	Cardiovascular	Drug-drug interaction	4	3	3	90%
Warfarin prescribed concomitantly with a NSAID *(Increased risk of bleeding)*	Cardiovascular	Drug-drug interaction	4	3	3	100%
Clopidogrel prescribed to a patient concomitantly with a NSAID *(Increased risk of bleeding)*	Cardiovascular	Drug-drug interaction	4	3	3	95%
Clopidogrel prescribed to a patient concomitantly with omeprazole or esomeprazole *(Antiplatelet effect of clopidogrel potentially reduced)*	Cardiovascular	Drug-drug interaction	3	4	3	95%
Macrolide antibiotic prescribed concomitantly with warfarin without appropriate dose adjustment or increased INR monitoring *(Increased risk of bleeding)*	Cardiovascular	Drug-drug interaction	4	4	4	95%

Low molecular weight heparin omitted to be prescribed for prophylaxis *(Increased risk of thrombosis)*	Cardiovascular	Omission of prophylactic treatment	4	4	4	95%
Lithium dose not adjusted or omitted in a patient with a lithium concentration above the therapeutic range (> 1.0 mmol/litre) *(Risk of lithium toxicity)*	Central Nervous System	Dosing	4	3	3	100%
Paracetamol prescribed at a dose of 4 g over a 24 hour to a patient under 50 kg *(Risk of hepatocellular toxicity)*[†]	Central Nervous System	Dosing	4	4	4	94%
Benzodiazepine or benzodiazepine-like drug prescribed to a patient with COPD *(Risk of respiratory depression)*	Central Nervous System	Clinical contraindication	3	3	3	90%
Antipsychotic, other than risperidone, prescribed to a patient for the management of the behavioural and psychological symptoms of dementia *(Increased risk of stroke)*	Central Nervous System	Clinical contraindication	4	3	3	100%
Tricyclic antidepressant prescribed to a patient with dementia *(Increased risk of worsening cognitive impairment)*	Central Nervous System	Clinical contraindication	3	3	3	90%
Selective serotonin re-uptake inhibitor prescribed to a patient with epilepsy *(Increased risk of seizure threshold being reduced)*	Central Nervous System	Clinical contraindication	3	3	3	95%
Selective serotonin re-uptake inhibitor prescribed to a patient with a history of clinically significant hyponatraemia (non-iatrogenic , sodium <130 mmol/litre in the previous 2 months) *(Increased risk of hyponatraemia)*	Central Nervous System	Clinical contraindication	3	3	3	95%
Prochlorperazine prescribed to a patient with parkinsonism *(Risk of exacerbating parkinsonism symptoms)*	Central Nervous System	Clinical contraindication	3	3	3	80%
NSAID prescribed to a patient with chronic renal failure *(Increased risk of deteriorating renal function)*	Central Nervous System	Clinical contraindication	3	3	3	95%
NSAID prescribed to a patient with a history of peptic ulcer disease or gastrointestinal bleeding without antisecretory drugs or mucosal protectants *(Increased risk of peptic ulceration and bleeding)*	Central Nervous System	Clinical contraindication	3	3	3	80%

NSAID prescribed to a patient with a history of heart failure *(Risk of exacerbation of heart failure)*	Central Nervous System	Clinical contraindication	3	3	3	85%
Lithium prescribed in conjunction with newly prescribed NSAIDs without dose adjustment or increased monitoring (*Increased risk of toxicity)*	Central Nervous System	Drug-drug interaction	4	3	3	100%
Lithium therapy prescribed in conjunction with newly prescribed loop or thiazide diuretics without dose adjustment or increased monitoring (*Increased risk of toxicity)*	Central Nervous System	Drug-drug interaction	4	3	3	100%
Tricyclic antidepressant prescribed at the same time as a Monoamine Oxidase Inhibitor *(Increased risk of serotonin syndrome)*	Central Nervous System	Drug-drug interaction	4	2	3	80%
Tramadol prescribed concomitantly with a Monoamine Oxidase Inhibitor *(Increased risk of serotonin syndrome)*	Central Nervous System	Drug-drug interaction	4	2	3	84%
Selective serotonin re-uptake inhibitor prescribed concomitantly with tramadol *(Increased risk of serotonin syndrome)*	Central Nervous System	Drug-drug interaction	3	4	3	100%
Selective serotonin re-uptake inhibitor prescribed concomitantly with aspirin without appropriate prophylaxis with antisecretory drugs or mucosal protectant *(Increased risk of gastrointestinal bleeding)*	Central Nervous System	Drug-drug interaction	3	3	3	95%
Citalopram prescribed concomitantly with other QT prolonging drugs *(Increased risk of arrhythmias)*	Central Nervous System	Drug-drug interaction	3	3	3	85%
Tramadol prescribed concomitantly with antiepileptics *(Increased risk of seizures in patients with uncontrolled epilepsy)*	Central Nervous System	Clinical contraindication	3	4	3	100%
Nefopam prescribed concomitantly with antiepileptics *(Increased risk of seizures in patients with uncontrolled epilepsy)*	Central Nervous System	Drug-drug interaction	3	3	3	80%
Phenytoin and enteral feeds prescribed to a patient concomitantly *(Reduced absorption of phenytoin)*	Central Nervous System	Drug-food interaction	3	3	3	85%
More than one paracetamol-containing product prescribed to a patient at a time *(Maximum dose exceeded)*	Central Nervous System	Duplicate therapy	4	3	3	95%

Benzodiazepines prescribed long-term (i.e. more than 2–4 weeks) *(Risk of dependence and withdrawal reactions)*	Central Nervous System	Duration	3	4	3	85%
Benzodiazepine or benzodiazepine-like drug prescribed long-term to a patient with depression *(Risk of dependence and withdrawal reactions)*	Central Nervous System	Duration	3	3	3	85%
Benzodiazepine-like drugs (e.g. Zopiclone) prescribed long-term (i.e. more than 2–4 weeks) *(Risk of dependence reactions)*	Central Nervous System	Duration	3	4	3	85%
Antipsychotic prescribed long-term (i.e. > 1 month) to a patient with parkinsonism *(Increased risk of worsening of extra-pyramidal side effects)*	Central Nervous System	Duration	3	3	3	85%
Regular opiates prescribed without concurrent use of laxatives *(Risk of severe constipation)*	Central Nervous System	Omission of prophylactic treatment	3	4	3	85%
Prescribing of incorrect or inequivalent morphine (opiate) dose via multiple routes. *(Risk of toxicity)*	Central Nervous System	Route	3	4	3	100%
Glibenclamide prescribed to an older adult with Type 2 diabetes mellitus *(Increased risk of hypoglycaemia)*	Endocrine	Clinical contraindication	3	3	3	80%
Metformin prescribed to a patient with eGFR < 30 ml/min/1.73m^2 *(Increased risk of lactic acidosis)*	Endocrine	Clinical contraindication	3	3	3	90%
Pioglitazone prescribed to a patient with heart failure *(Risk of exacerbation of heart failure)*	Endocrine	Clinical contraindication	3	3	3	85%
Soluble insulin prescribed to a patient on a when required basis *(Increased risk of serious episodes of hypoglycaemia and nocturnal hypoglycaemia post dose)*	Endocrine	Frequency	3	3	3	90%
Insulin prescribed to a patient at an inappropriate time, allowing for an administration without food (except once daily long-acting insulins) *(Increased risk of hypoglycaemia)*	Endocrine	Timing of dose	4	3	3	95%
Domperidone prescribed at a total daily dose exceeding 30 mg/day in adults > 60 years old *(Increased risk of QTc prolongation, serious ventricular arrhythmia and sudden cardiac death)*	Gastrointestinal	Dosing	4	3	3	95%

Diphenoxylate, loperamide, codeine phosphate prescribed as antidiarrhoeal agents for treatment of severe infective gastroenteritis (e.g. bloody diarrhoea, high fever, or severe systemic toxicity) *(Increased risk of exacerbation or protraction of infection)*	Gastrointestinal	Clinical contraindication	3	3	3	85%
Metoclopramide prescribed to a patient with parkinsonism *(Risk of exacerbating parkinsonism symptoms)*	Gastrointestinal	Clinical contraindication	3	4	3	85%
Colestyramine prescribed to a patient at the same time as any other oral medication *(Risk of poor clinical effect owing to reduced absorption of medications)* [†]	Gastrointestinal	Drug-drug interaction	3	4	3	90%
Orlistat prescribed at the same time of day as oral antiepileptics *(Orlistat can reduce the absorption of antiepileptics, leading to loss of seizure control)*	Gastrointestinal	Drug-drug interaction	3	3	3	90%
Diphenoxylate, loperamide, or codeine phosphate prescribed as antidiarrhoeal agents for treatment of diarrhoea of unknown cause *(Increased risk of exacerbating constipation with overflow diarrhoea)*	Gastrointestinal	Indication	3	3	3	85%
Penicillin containing compound prescribed to a penicillin allergic patient without reasoning (e.g. a mild or non-allergy such as diarrhoea or vomiting entered as an allergy where the indication for penicillin is compelling) *(Risk of hypersensitivity reactions)*	Infection	Allergy	4	3	3	100%
Gentamicin dose calculated based on actual body weight rather than ideal body weight in an obese patient (BMI > 30 kg/m^2) *(Risk of excessive dosing and toxicity)*	Infection	Dosing	4	4	4	100%
Amphotericin B prescribed without stating the brand name and the dose in mg/kg *(Risk of fatal overdose due to confusion between lipid based and non-lipid formulations)*	Infection	Drug name	5	3	4	90%
Cephalosporin antibiotic prescribed to an older adult (except under the direction of Microbiology or for suspected meningitis) *(Increased risk of antibiotic-associated infections)*	Infection	Clinical contraindication	3	3	3	85%

Gentamicin prescribed to a patient with renal impairment without dose adjustment *(Increased risk of toxicity)*	Infection	Dosing	4	3	3	95%
Gentamicin prescribed to an adult patient with normal renal function in a dose exceeding 7 mg/kg/day *(Increased risk of toxicity)*	Infection	Dosing	4	3	3	90%
Vancomycin prescribed intravenously to a patient with renal impairment without dose adjustment *(Increased risk of toxicity)*	Infection	Clinical contraindication	4	3	3	95%
Quinolone antibiotic prescribed to a patient with epilepsy *(Increased risk of seizure threshold being reduced)*	Infection	Clinical contraindication	3	3	3	100%
Nitrofurantoin prescribed to a patient with eGFR < 60 ml/minute/1.73m^2 *(Risk of peripheral neuropathy and inadequate concentration in urine)* †	Infection	Clinical contraindication	3	3	3	90%
Quinolone prescribed to a patient who is also receiving theophylline *(Possible increased risk of convulsions)*	Infection	Drug-drug interaction	3	3	3	95%
Atazanavir prescribed concomitantly with a proton-pump inhibitor *(Concentration of atazanavir potentially reduced, reducing therapeutic effect)*	Infection	Drug-drug interaction	3	3	3	95%
Vancomycin prescribed intravenously over less than 60 minutes *(Rapid infusion of vancomycin can cause severe reactions)*	Infection	Intravenous rate	3	3	3	90%
Brand specific prescribing of tacrolimus preparations *(Brands vary in their dosing and pharmacokinetics)*	Misc	Drug name	4	3	3	85%
Methotrexate prescribed to a patient with a clinically significant drop in white cell count or platelet count *(Risk of bone marrow suppression)*	Misc	Clinical contraindication	4	3	3	95%
Methotrexate prescribed to a patient with abnormal liver function tests *(Risk of liver toxicity)*	Misc	Clinical contraindication	4	3	3	83%
Potassium chloride supplements continued for longer than is required (reference range 3.5–5.3 mmol/litre) *(Increased risk of hyperkalaemia)*	Misc	Clinical contraindication	4	3	3	100%

Methotrexate prescribed concomitantly with trimethoprim *(Increased risk of haematological toxicity)*	Misc	Drug-drug interaction	3	3	3	89%
Weekly dose of an oral bisphosphonate prescribed daily *(Risk of hypocalcaemia)*	Misc	Frequency	3	3	3	89%
Oral methotrexate prescribed to a patient with an inappropriate frequency *(Increased risk of toxicity)*	Misc	Frequency	5	2	3	89%

†Additional indicators recommended by panellists in the exploratory round and included in round one (n=13)
‡Indicators where the text was suggested to be modified by panellists in the exploratory round for round one (n=2)
Median risk scores: 1: Low risk; 2: Moderate risk, 3: High risk; 4: Extreme risk

Appendix 4 – Indicators not considered high or extreme risk by consensus of at least 80%

Prescribing safety indicator *(harm)*
Proton-pump inhibitors prescribed at the same time as antacid formulations *(Reduced therapeutic effect of the proton-pump inhibitor)*
Thiazide diuretic prescribed to a patient with a history of gout *(Increased risk of exacerbating symptoms in pre-existing gout)*
Thiazide prescribed to a patient with chronic kidney disease (CKD) stage 3 (eGFR< 45/ml/min/1.73m^2) or above *(Increased risk of adverse effects)*
Beta-adrenoceptor blocking drug prescribed to a patient with asthma *(Increased risk of bronchospasm and acute deterioration)*
Aliskiren prescribed concomitantly with ACE inhibitors or angiotensin-II receptor antagonists *(Increased risk of serious adverse cardiovascular and renal outcomes)*
Aliskiren prescribed to a patient with severe renal impairment, eGFR< 30 ml/min/1.73m^2 *(Risk of hyperkalaemia)*
Long-acting inhaled antimuscarinic prescribed concomitantly with a short acting nebulised antimuscarinic *(Increased risk of additive adverse effects)*
SSRI prescribed concomitantly with pethidine *(Increased risk of serotonin syndrome)*
Selective Serotonin Re-uptake Inhibitors prescribed at the same time as Monoamine Oxidase Inhibitors *(Increased risk of serotonin syndrome)*
Metoclopramide prescribed to a patient <20 years (except in cases of severe intractable vomiting of known cause, or due to cytotoxics/radiotherapy)(*Increased risk of extrapyramidal side-effects)*
Two concomitant opiate analgesics that are not in line with the WHO pain ladder *(Injudicious use of two opiates)*
Aspirin prescribed to a child $\leq$ 16 years (except in Kawasaki's disease) *(Increased risk of Reye's syndrome)*
Vancomycin prescribed intravenously for the treatment of *Clostridium difficile* infection *(Intravenous vancomycin has limited therapeutic effect)*
Oral quinolone antibiotic prescribed at the same time as iron *(Reduced absorption of quinolones)*
Triazole antifungal prescribed at the same time as fentanyl *(Increased risk of opiate toxicity)*
Rifampicin prescribed concomitantly with ritonavir *(Ritonavir concentration can be reduced, reducing its effect)*
Bisphosphonate prescribed to a patient with an inappropriate timing (Increased risk of adverse effects and possible reduced absorption if given after food)
Bisphosphonate prescribed to a patient at the same time of day as calcium (Bisphosphonate absorption reduced by calcium salts)
Methotrexate prescribed on the same day as folic acid (Reduced efficacy of methotrexate)
Allopurinol prescribed concomitantly with azathioprine (Allopurinol enhances effect of azathioprine and increases risk of toxicity)
Allopurinol prescribed concomitantly with mercaptopurine *(Allopurinol enhances effect of mercaptopurine and increases risk of toxicity)*
Calcium resonium prescribed when the potassium concentration is within the desired reference range (3.5–5.3 mmol/litre) *(Risk of hypokalaemia)*
Potassium chloride infusions exceeding 40 mmol/litre given via the peripheral route *(Peripheral administration risks venous pooling, which can lead to sudden high concentrations of potassium chloride being delivered to the heart provoking an arrhythmia)*

Prescribing safety indicator (harm)
Selective COX-2 inhibitor NSAID prescribed to a patient with cardiovascular disease *(Increased risk of thrombotic events)*
More than one NSAID prescribed to a patient at a time *(Increased risk of bleeding)*
Allopurinol prescribed at a dose exceeding 100 mg in a patient with renal impairment *(Risk of accumulation and subsequent toxicity)*
Live vaccine prescribed to an immunosuppressed patient, including those on corticosteroids *(Increased risk of reaction or infection)*
Two loop diuretics prescribed concomitantly *(Increased risk of adverse effects)*
Long-acting beta-2-agonist inhaler prescribed to a patient who is not also on an inhaled corticosteroid *(Evidence base - not in line with British Thoracic Society guidelines)*

Appendix 5 – Themes and detailed codes for pharmacist-physician communications

Major theme	Code
Contraindication	The drug is cautioned or contraindicated as a result of patient comorbidities
	The drug is cautioned or contraindicated as a result of recent test results
	The drug should be used with caution as the patient is at risk of falls
	The patient has reported an intolerance to the drug
	The patient is allergic to the drug
	There is a potential for cross-reactivity
Dose/Frequency	Change the prescription to be given on a 'when required' basis as the patient is refusing
	Change the regular prescription to on a 'when required' basis
	The dose is higher than the pre-admission dose
	The dose is lower than the pre-admission dose
	The dose is too high
	The dose is too low
	The dose requires review
	The dose/strength has been documented incorrectly
	The frequency is too high
	The frequency is too high compared to pre-admission
	The frequency is too low
	The frequency is too low compared to pre-admission
	The frequency of dosing requires review
	The prescription should be documented as a 'continuous' frequency
	The prescription should be for a one-off dose only (i.e. not regular)
	The total daily dose is correct, but split incorrectly throughout the day
	The wrong dose units have been prescribed
	There is a dosing error as a result of when the route/form has been changed

Drug Form/Route	**A change in formulation is required because the patient has an enteral feeding tube**
	A change in formulation is required to be consistent with the patient's pre-admission form
	An alternative route of administration is recommended
	Change the formulation from a liquid to a solid dose form
	Change the formulation to a modified-release form, to be consistent with pre-admission meds
	Change the formulation to a standard release form, to be consistent with pre-admission meds
	Change the formulation to enteric-coated, to be consistent with pre-admission meds
	Change the formulation to liquid or soluble form
	Change the formulation to modified-release
	Change the route from intravenous to oral
	Change the route from oral to intravenous
	Change to standard release
	The route is incorrect for the drug
	The route of administration is inappropriate for the indication
	The route requires review
	The use of multiple routes is not appropriate for the drug
Drug Interaction	There is a pharmacodynamic drug-drug interaction
	There is a pharmacokinetic drug-drug interaction
Drug Selection	A combination has been prescribed, but the patient is only on a single component
	Recommends an alternative treatment
	The drug choice does not adhere to guidelines
	The drug has been prescribed incorrectly by brand or generic name, not consistent with the eP system practice
	The drug is no longer indicated
	The patient is on a different brand of the drug and this should be 'brand specific' when prescribed
	The patient is on a different drug of the same class that has been prescribed
	The patient is on the drug, but takes it as a different brand (Adcal D3 versus Calcichew D3)
	The patient takes the drug as a different salt (e.g. ferrous sulphate, not fumarate)

	The strength prescribed is higher than that used pre-admission
	The strength prescribed is lower than that used pre-admission
	The strength prescribed is too high
	The strength prescribed is too low
	The wrong drug has been prescribed as a result of a selection error
	There is a duplicate prescription with a drug of the same class
	There is a duplicate prescription with the same drug
	There is a duplicate treatment prescribed for the same indication
Drug Use/Administration process	A change in formulation is required because the patient has swallowing difficulties
	A duration is needed on the prescription
	An alternative drug is recommended because it cannot be crushed/opened for administration
	An alternative drug recommended as it is not suitable for enteral feeding tubes
	Change the drug device to be consistent with pre-admission meds
	Doses have been missed for no obvious reason
	Review the prescription as the patient is refusing it
	The dose prescribed is immeasurable
	The drug cannot be administered as there is no intravenous access
	The drug has been prescribed at the wrong time of day (according to practice/BNF recommendations)
	The drug is to be re-started
	The drug is to be stopped (or paused)
	The drug should be prescribed as a reducing regimen
	The duration of treatment requires review
	The patient has never taken or used the drug that has been prescribed
	The patient no longer takes or uses the drug prescribed
	The prescription is inappropriate for discharge (e.g. intravenous form)
	The route of administration requires further information (e.g. which eye?)
	Timing of the dose (hour or day) requires adjusting to be consistent with the patient's usual regimen pre-admission

Logistics	Information requested relating to controlled drug prescription writing requirements
	Informing physician that the prescription was validated and signed-off in error
	The physician's grade does not give him/her authority to prescribe the drug
	The drug has been prescribed for the wrong patient
	The drug is not available as it does not exist as prescribed
	The drug is not available due to a manufacturing delay
	The drug not available as it is not stocked in the hospital
	The maximum frequency is required to be documented on the 'when required' prescription
Omission	Recommends a drug is started to optimise treatment (e.g. thiamine)
	The patient takes a combination preparation, but only a single component of this has been prescribed
	There is an omission according to the patient's drug history
	There is an omission of required treatment (i.e. anti-emetics prior to chemotherapy)
	There is an omission on the 'To Take Out' (TTO) prescription
	Venous thromboembolism (VTE) prophylaxis has been omitted and requires initiation
Supporting Information	Additional information is provided on the patient's drug history
	Endorsement (e.g. with meals)
	Information is provided on a patient's test result(s) (e.g. potassium concentration)
	Information is provided on the administration, reconstitution or supply of a medicine
	Information is provided on the dosing regimen going forward (anticipatory)
	Information is provided on the duration of treatment
	Information is provided on the indication for treatment
	Information is provided on the patient's allergy history
	Information is provided on the patient's usual dosing regimen (but no change/review requested)
	Information is provided on the potential adverse effects of treatment
	Information is provided on the usual dosing regimen for the drug (but no change/review requested)

	Information is requested on the indication for treatment
	Information is requested on the requirement of the drug on discharge
	Information provided on the patient's response to treatment
	Informing physician that the patient is non-adherent with treatment
	Monitor blood pressure/pulse
	Monitor for adverse effects of treatment
	Monitor for beneficial effects of treatment
	Monitor glucose concentration
	Monitor pain control
	Monitor the patient’s biochemical parameters
	Monitor the patient’s haematological parameters
	Monitor the patient’s liver function tests
	Monitor the patient’s thyroid function tests
	Monitor the patient’s weight
	Request for falls assessment to be updated
	Request is made for the patient’s weight to be taken and documented
	Request is made for the venous thromboembolism assessment to be updated
	Requests serum/plasma concentration taken
	The pharmacist documents a discussion with the physician relating to the prescription
Other	Recommends prophylactic treatment is commenced (other than VTE, e.g. proton-pump inhibitor for a patient on a non-steroidal anti-inflammatory drug)
	Request is made for the TTO to be updated
	Request patient is counselled on treatment
	Request that the drug history is clarified
	Requests input from another healthcare professional (e.g. speech and language assessment)
	The drug name has been prescribed such that it overrides all decision support
	The pharmacist directs the physician to read the drug history or prescription endorsements

Appendix 6 – Frequency of review messages assigned by factor

	No. of messages assigned	Percentage of total (%)
Day of the week review message assigned		
Monday	7899	22.9%
Tuesday	7373	21.4%
Wednesday	6441	18.7%
Thursday	6175	17.9%
Friday	6151	17.8%
Sat/Sun	467	1.4%
Hour of day review message assigned		
00:00–12:59	21238	61.5%
13:00–23:59	13268	38.5%
Time from prescription generated to message assigned		
< 12 hours	8913	25.8%
12–23:59 hours	9636	27.9%
1–6 days	13278	38.5%
7+ days	2679	7.8%
Grade of pharmacist		
6	10532	30.5%
7	16302	47.2%
8	7672	22.2%
Message assigned to high-risk medicine		
No	24459	70.9%
Yes	10047	29.1%
Message assigned to high-risk error		
No	33189	96.2%
Yes	1317	3.8%
Free-text drug entry		
No	64142	99.9%
Yes	364	0.01%
Message related to medicines reconciliation		
No	19211	55.7%
Yes	15295	44.3%
Communication theme		
Contraindication	1249	3.6%
Dose/Frequency	9361	27.1%
Drug Form/Route	2050	5.9%
Drug Interaction	753	2.2%
Drug Selection	3308	9.6%
Drug Use/Administration	4790	13.9%
Logistics	622	1.8%
Omission	3696	10.7%
Other	724	2.1%
Supporting Information	7953	23.0%

	No. of messages assigned	Percentage of total (%)
Speciality		
Medical Admissions	6663	19.3%
Critical Care and Burns	1744	5.1%
General Medicine	8429	24.4%
General Surgery	2074	6.0%
Medical Specialities	10294	29.8%
Surgical Specialities	3388	9.8%
TNO	1914	5.5%
Medicine type		
Cardiovascular	8458	24.5%
Central nervous system	7897	22.9%
Endocrine	2665	7.7%
Eye, Ear, nose and oropharynx	772	2.2%
Gastrointestinal	3091	9.0%
Infection	3573	10.4%
Malignant disease and immunosuppression	307	0.9%
Musculoskeletal and joint disease	872	2.5%
Nutrition and blood	3421	9.9%
Obstetrics, gynaecology and urinary-tract disorders	526	1.5%
Other	112	0.3%
Respiratory	2417	7.0%
Skin	395	1.1%
High-risk medicine		
Amiodarone	232	2.3%
Antibiotics	3102	30.9%
Antipsychotics	398	4.0%
Benzodiazepine	545	5.4%
DOACs	0	0.0%
Insulin	229	2.3%
LMWH	2195	21.8%
Methotrexate	37	0.4%
NSAID	345	3.4%
Opioid	2175	21.6%
Phenytoin	136	1.4%
Potassium	469	4.7%
Warfarin	184	1.8%
Regularity prescription		
Regular	27276	79.0%
As Required	3669	10.6%
Once-Only	266	0.8%
TTO	3295	9.5%

Appendix 7 – High-risk errors communicated via the review message

Prescribing indicator of high risk-error	No. of messages
Paracetamol prescribed at a dose of 4 g over a 24 hour to a patient under 50 kg *(Risk of hepatocellular toxicity)*	350
Statin prescribed concomitantly with a macrolide antibiotic *(Increased risk of myopathy)*	203
Low molecular weight heparin prescribed to a patient with renal impairment without dose adjustment *(Increased risk of bleeding)*	156
Potassium chloride supplements continued for longer than is required (reference range 3.5–5.3 mmol/litre) *(Increased risk of hyperkalaemia)*	139
Nitrofurantoin prescribed to a patient with eGFR < 60 ml/minute/1.73m^2 *(Risk of peripheral neuropathy and inadequate concentration in urine)*	102
Low molecular weight heparin prescribed without the patient's weight being used to calculate the treatment dose *(Risk of subtherapeutic or supratherapeutic dosing)*	74
More than one paracetamol-containing product prescribed to a patient at a time *(Maximum dose exceeded)*	48
Low molecular weight heparin omitted to be prescribed for prophylaxis *(Increased risk of thrombosis)*	28
Selective serotonin re-uptake inhibitor prescribed concomitantly with tramadol *(Increased risk of serotonin syndrome)*	23
Amiodarone prescribed concomitantly with simvastatin 40 mg or above *(Increased risk of myopathy)*	16
Penicillin containing compound prescribed to a penicillin allergic patient without reasoning (e.g. a mild or non-allergy such as diarrhoea or vomiting entered as an allergy where the indication for penicillin is compelling) *(Risk of hypersensitivity reactions)*	14
Domperidone prescribed at a total daily dose exceeding 30 mg/day in adults > 60 years old *(Increased risk of QTc prolongation, serious ventricular arrhythmia and sudden cardiac death)*	13
Macrolide antibiotic prescribed concomitantly with warfarin without appropriate dose adjustment or increased INR monitoring *(Increased risk of bleeding)*	13
Warfarin prescribed concomitantly with a NSAID *(Increased risk of bleeding)*	12
Quinolone antibiotic prescribed to a patient with epilepsy *(Increased risk of seizure threshold being reduced)*	12
Clopidogrel prescribed to a patient concomitantly with omeprazole or esomeprazole *(Antiplatelet effect of clopidogrel potentially reduced)*	11
Colestyramine prescribed to a patient at the same time as any other oral medication *(Risk of poor clinical effect owing to reduced absorption of medications)*	9
ACE inhibitor or angiotensin-II receptor antagonist prescribed to a patient with a potassium level ≥5.0 mmol/litre *(Can cause or exacerbate hyperkalaemia)*	8
Antiplatelet prescribed to a patient with a concurrent bleeding disorder *(Increased risk of bleeding)*	8
Tramadol prescribed concomitantly with antiepileptics *(Increased risk of seizures in patients with uncontrolled epilepsy)*	8
Low molecular weight heparin prescribed at a dose exceeding the maximum as stated in the product literature *(Risk of bleeding increased)*	7
Quinolone prescribed to a patient who is also receiving theophylline *(Possible increased risk of convulsions)*	6
Vancomycin prescribed intravenously to a patient with renal impairment without dose adjustment *(Increased risk of toxicity)*	6
Insulin prescribed to a patient at an inappropriate time, allowing for an administration without food (except once daily long-acting insulins) *(Increased risk of hypoglycaemia)*	5

Benzodiazepines prescribed long-term (i.e. more than 2–4 weeks) *(Risk of dependence and withdrawal reactions)*	4
Selective serotonin re-uptake inhibitor prescribed concomitantly with aspirin without appropriate prophylaxis with antisecretory drugs or mucosal protectant *(Increased risk of gastrointestinal bleeding)*	4
Pioglitazone prescribed to a patient with heart failure *(Risk of exacerbation of heart failure)*	4
Selective serotonin re-uptake inhibitor prescribed to a patient with a history of clinically significant hyponatraemia (non-iatrogenic , sodium <130 mmol/litre in the previous 2 months) *(Increased risk of hyponatraemia)*	4
NSAID prescribed to a patient with a history of peptic ulcer disease or gastrointestinal bleeding without antisecretory drugs or mucosal protectants *(Increased risk of peptic ulceration and bleeding)*	3
NSAID prescribed to a patient with chronic renal failure *(Increased risk of deteriorating renal function)*	3
Selective serotonin re-uptake inhibitor prescribed to a patient with epilepsy *(Increased risk of seizure threshold being reduced)*	3
Potassium-sparing diuretic (excluding aldosterone antagonists) prescribed to a patient also receiving an ACE inhibitor or angiotensin-II receptor antagonist *(Increased risk of severe hyperkalaemia)*	2
Gentamicin prescribed to a patient with renal impairment without dose adjustment *(Increased risk of toxicity)*	2
Metformin prescribed to a patient with eGFR < 30 ml/min/1.73m^2 *(Increased risk of lactic acidosis)*	2
Methotrexate prescribed concomitantly with trimethoprim *(Increased risk of haematological toxicity)*	2
NSAID prescribed to a patient with a history of heart failure *(Risk of exacerbation of heart failure)*	2
Regular opiates prescribed without concurrent use of laxatives *(Risk of severe constipation)*[‡]	2
Antipsychotic prescribed long-term (i.e. > 1 month) to a patient with parkinsonism *(Increased risk of worsening of extra-pyramidal side effects)*	2
Aspirin prescribed to a patient with a past medical history of peptic ulcer disease without antisecretory drugs or mucosal protectants *(Increased risk of peptic ulceration and risk of bleeding)*	1
Gentamicin dose calculated based on actual body weight rather than ideal body weight in an obese patient (BMI > 30 kg/m^2) *(Risk of excessive dosing and toxicity)*	1
Soluble insulin prescribed to a patient on a when required basis *(Increased risk of serious episodes of hypoglycaemia and nocturnal hypoglycaemia post dose)*	1
Metoclopramide prescribed to a patient with parkinsonism *(Risk of exacerbating parkinsonism symptoms)*	1
Lithium prescribed in conjunction with newly prescribed NSAIDs without dose adjustment or increased monitoring (*Increased risk of toxicity)*	1
Tramadol prescribed concomitantly with a Monoamine Oxidase Inhibitor *(Increased risk of serotonin syndrome)*	1
Warfarin prescribed to a patient with a concurrent bleeding disorder *(Increased risk of bleeding)*	1
Total	**1317**

Appendix 8 – Number of messages relating to each code

Code	No. of messages
Information provision - Patient dosing pre-admission (no change)	3638
There is an omission according to the patient's drug history	2820
The dose is lower than the pre-admission dose	1781
The dose is too high	1358
The frequency is too low	1052
A duration is needed on the prescription	1041
The duration of treatment requires review	1036
The dose is too low	1029
The dose is higher than the pre-admission dose	906
There is a duplicate prescription with a drug of the same class	812
The frequency is too low compared to pre-admission	708
Change the formulation to a modified-release form, to be consistent with pre-admission meds	699
The frequency is too high	698
Information is provided on the usual dosing regimen for the drug (but no change/review requested)	629
Venous thromboembolism prophylaxis has been omitted and requires initiation	620
The patient is on a different drug of the same class that has been prescribed	608
The drug should be used with caution as the patient is at risk of falls	580
There is a pharmacokinetic drug-drug interaction	564
The patient no longer takes or uses the drug prescribed	558
Request is made for the 'To Take Out' (TTO) to be updated	496
The drug not available as it is not stocked in the hospital	461
The frequency is too high compared to pre-admission	450
The dose requires review	439
There is a duplicate prescription with the same drug	374
The patient has never taken or used the drug that has been prescribed	360
Request is made for the patient's weight to be taken and documented	350
Change the drug device to be consistent with pre-admission meds	349
The drug choice does not adhere to guidelines	344
Information is provided on the duration of treatment	339

Information is provided on the dosing regimen going forward (anticipatory)	335
The patient takes a combination preparation, but only a single component of this has been prescribed	333
The drug is cautioned or contraindicated as a result of patient comorbidities	328
There is an omission on the TTO prescription	321
The drug is to be stopped (or paused)	316
Change the regular prescription to on a 'when required' basis	310
Change the formulation to liquid or soluble form	299
A change in formulation is required to be consistent with the patient's pre-admission form	288
Timing of the dose (hour or day) requires adjusting to be consistent with the patient's usual regimen pre-admission	271
Monitor the patient's biochemical parameters	271
The drug is no longer indicated	268
The total daily dose is correct, but split incorrectly throughout the day	257
Recommends an alternative treatment	240
Information is provided on a patient's test result(s) (e.g. potassium concentration)	234
Information is provided on the administration, reconstitution or supply of a medicine	218
The pharmacist documents a discussion with the physician relating to the prescription	216
There is a pharmacodynamic drug-drug interaction	190
Information is requested on the indication for treatment	190
Recommends a drug is started to optimise treatment (e.g. thiamine)	179
Requests serum/plasma concentration taken	175
Information is requested on the requirement of the drug on discharge	167
A change in formulation is required because the patient has an enteral feeding tube	165
The drug should be prescribed as a reducing regimen	163
Review the prescription as the patient is refusing it	158
The drug is cautioned or contraindicated as a result of recent test results	151
There is a duplicate treatment prescribed for the same indication	150
There is a dosing error as a result of when the route/form has been changed	146
Change the route from intravenous to oral	143
Monitor the patient's haematological parameters	140
Additional information is provided on the patient's drug history	138

The patient is on a different brand of the drug and this should be 'brand specific' when prescribed	138
Change the formulation to enteric-coated, to be consistent with pre-admission meds	134
The drug has been prescribed at the wrong time of day (according to practice/BNF recommendations)	131
A change in formulation is required because the patient has swallowing difficulties	123
The dose prescribed is immeasurable	122
The patient is allergic to the drug	114
The route is incorrect for the drug	110
Change the formulation to a standard release form, to be consistent with pre-admission meds	93
The patient is on the drug, but takes it as a different brand (Adcal D3 versus Calcichew D3)	93
The frequency of dosing requires review	83
Information is provided on the potential adverse effects of treatment	77
Endorsement (e.g. with meals)	75
The drug name has been prescribed such that it overrides all decision support	72
The patient takes the drug as a different salt (e.g. ferrous sulphate, not fumarate)	69
The strength prescribed is lower than that used pre-admission	65
The drug is not available due to a manufacturing delay	59
The strength prescribed is higher than that used pre-admission	55
The patient has reported an intolerance to the drug	54
The pharmacist directs the physician to read the drug history or prescription endorsements	54
The maximum frequency is required to be documented on the 'when required' prescription	53
The prescription is inappropriate for discharge (e.g. intravenous form)	53
Request that the drug history is clarified	49
Change the prescription to be given on a 'when required' basis as the patient is refusing	46
Monitor blood pressure/pulse	45
The dose/strength has been documented incorrectly	44
The drug is to be re-started	41
Recommends prophylactic treatment is commenced (other than VTE, e.g. proton-pump inhibitor for a patient on a non-steroidal anti-inflammatory drug)	37
A combination has been prescribed, but the patient is only on a single component	35
Monitor for adverse effects of treatment	32
The wrong dose units have been prescribed	31

The drug is not available as it does not exist as prescribed	28
Informing physician that the prescription was validated and signed-off in error	28
The route requires review	26
Request is made for the venous thromboembolism assessment to be updated	26
There is a potential for cross-reactivity	22
An alternative drug is recommended because it cannot be crushed/opened for administration	21
Change the route from oral to intravenous	20
An alternative route of administration is recommended	19
There is an omission of required treatment (i.e. anti-emetics prior to chemotherapy)	17
The prescription should be for a one-off dose only (i.e. not regular)	17
Change the formulation from a liquid to a solid dose form	17
Informing physician that the patient is non-adherent with treatment	16
Information requested relating to controlled drug prescription writing requirements	16
An alternative drug recommended as it is not suitable for enteral feeding tubes	15
Change the formulation to modified-release	13
Monitor glucose concentration	13
Doses have been missed for no obvious reason	12
The route of administration is inappropriate for the indication	12
The wrong drug has been prescribed as a result of a selection error	11
The drug has been prescribed incorrectly by brand or generic name, not consistent with the eP system practice	10
Requests input from another healthcare professional (e.g. speech and language assessment)	10
The drug cannot be administered as there is no intravenous access	10
The route of administration requires further information (e.g. which eye?)	9
The strength prescribed is too low	7
Change to standard release	7
Information is provided on the patient’s allergy history	7
Request patient is counselled on treatment	6
Monitor pain control	6
The prescription should be documented as a 'continuous' frequency	5
Information provided on the patient's response to treatment	5

The use of multiple routes is not appropriate for the drug		5
The physicians grade does not give him/her authority to prescribe the drug		4
Information is provided on the indication for treatment		4
Monitor the patient's thyroid function tests		4
Monitor for beneficial effects of treatment		3
Request for falls assessment to be updated		2
Monitor the patient's liver function tests		2
The strength prescribed is too high		2
Additional information is provided on the patient's drug history		1
Monitor the patient's weight		1
The drug has been prescribed for the wrong patient		1
	Total	**34506**

Appendix 9 – Chi-Square and generalised estimating equation results for sign-off rates of review messages

Considering: 1) Temporal; 2) Message and; 3) Prescription factors. The results from the GEE have been reported alongside the Chi Square to allow for comparisons. Chi analysis shown is before any exclusions as a result of zero numbers and multicollinearity.

1) Temporal factors

			Chi-Square		GEE	
			Sign-Off		Sign-Off	
		Total no. of messages	Number signed off %(n)	p-value	Odds Ratio (95% CI)	p-value
Day of the week review message assigned				**<0.001***		**0.002***
	Monday	7899	47.0% (n=3715)		1	
	Tuesday	7373	47.4% (n=3494)		1.020 (0.953–1.093)	0.563
	Wednesday	6441	47.4% (n=3055)		1.004 (0.935–1.079)	0.903
	Thursday	6175	45.3% (n=2798)		0.937 (0.871–1.008)	0.081
	Friday	6151	45.4% (n=2792)		0.937 (0.872–1.008)	0.082
	Sat/Sun	467	36.6% (n=171)		0.706 (0.570–0.875)	0.001*
Hour of day review message assigned				**0.309**		**0.086**
	00:00–12:59	21238	46.7% (n=9909)		1	
	13:00–23:59	13268	46.1% (n=6116)		1.043 (0.994–1.093)	0.086
Time taken to assign review message				**0.025***		**<0.001***
	< 12 hours	8913	45.6% (n=4068)		1	
	12–23:59 hours	9636	47.6% (n=4587)		0.971 (0.911–1.035)	0.367
	1-6 days	13278	46.0% (n=6105)		0.892 (0.837–0.949)	<0.001*
	7+ days	2679	47.2% (n=1265)		1.020 (0.926–1.124)	0.682

2) Message factors

			Chi-Square		GEE	
			Sign-Off		Sign-Off	
		Total no. of messages	Number signed off %(n)	p-value	Odds Ratio (95% CI)	p-value
Grade of pharmacist				**0.561**		**0.010***
	6	10532	46.4% (n=4889)		1	
	7	16302	46.7% (n=7611)		0.980 (0.925–1.039)	0.506
	8	7672	45.9% (n=3525)		0.899 (0.835–0.967)	0.004*
Message assigned to a high-risk medicine				**<0.001***		**<0.001***
	No	24459	47.8% (n=11703)		1	
	Yes	10047	43.0% (4322)		0.841 (0.789–0.895)	<0.001*
Message assigned to a high-risk error				**0.387**		#
	No	33189	46.4% (n=15398)		#	#
	Yes	1317	47.6% (n=627)		#	#
Message relates to medicines reconciliation				**<0.001***		**0.004***
	No	19211	43.1% (n=8272)		1	
	Yes	15295	50.7% (n=7753)		1.082 (1.025–1.142)	0.004*
Message associated with prescription				**<0.001***		#
	No	3406	52.6% (n=1793)		#	#
	Yes	31100	45.85% (n=14232)		#	#
Communication theme				**<0.001***		**<0.001***
	Dose/Frequency	9361	54.2% (n=5073)		1	
	Contraindication	1249	33.5% (n=419)		0.498 (0.439–0.566)	<0.001*
	Drug Form/Route	2050	44.0% (n=902)		0.640 (0.581–0.705)	<0.001*
	Drug Interaction	753	46.6% (n=351)		0.733 (0.633–0.850)	<0.001*
	Drug Selection	3308	35.6% (n=1177)		0.537 (0.494–0.584)	<0.001*
	Drug Use/Administration	4790	39.4% (n=1885)		0.604 (0.562–0.649)	<0.001*
	Logistics	622	37.1% (n=231)		0.560 (0.471–0.665)	<0.001*
	Omission	3696	50.1% (n=1851)		0.820 (0.764–0.880)	<0.001*
	Other	724	39.2% (n=284)		0.864 (0.733–1.018)	0.080
	Supporting Information	7953	48.4% (n=3852)		0.801 (0.755–0.850)	<0.001*

3) Prescription factors			Chi-Square		GEE	
			Sign-Off		Sign-Off	
		Total no. of messages	Number signed off %(n)	p-value	Odds Ratio (95% CI)	p-value
Speciality				**<0.001***		**<0.001***
	Medical Admissions	6663	52.5% (n=3501)		1	
	Critical Care and Burns	1744	63.0% (n=1099)		2.038 (1.796–2.314)	<0.001*
	General Medicine	8429	49.2% (n=4147)		1.111 (1.024–1.205)	0.011*
	General Surgery	2074	33.3% (n=690)		0.558 (0.498–0.625)	<0.001*
	Medical Specialities	10294	41.5% (n=4267)		0.840 (0.780–0.906)	<0.001*
	Surgical Specialities	3388	41.9% (n=1421)		0.837 (0.763–0.919)	<0.001*
	TNO	1914	47.0% (n=900)		1.090 (0.970–1.226)	0.147
BNF category				**<0.001***		**<0.001***
	Cardiovascular	8458	51.3% (n=4336)		1	
	Central nervous system	7897	44.4% (n=3510)		0.955 (0.891–1.023)	0.189
	Endocrine	2665	51% (n=1360)		0.993 (0.904–1.091)	0.883
	Eye, Ear, nose and oropharynx	772	43.3% (n=334)		0.765 (0.650–0.901)	0.001*
	Gastrointestinal	3091	45.9% (n=1418)		0.894 (0.815–0.981)	0.018*
	Infection	3573	45.7% (n=1634)		0.991 (0.905–1.086)	0.852
	Malignant disease and immunosuppression	307	49.2% (n=151)		1.054 (0.830–1.337)	0.667
	Musculoskeletal and joint disease	872	42.3% (n=369)		0.842 (0.724–0.980)	0.027*
	Nutrition and blood	3421	43.9% (n=1502)		0.796 (0.729–0.868)	<0.001*
	Obstetrics, gynaecology and urinary-tract disorders	526	45.6% (n=240)		0.791 (0.656–0.955)	0.015*
	Other	112	28.6% (n=32)		0.511 (0.328–0.796)	0.003*
	Respiratory	2417	41.4% (n=1000)		0.702 (0.634–0.778)	<0.001*
	Skin	395	35.2% (n=139)		0.579 (0.462–0.727)	<0.001*

Regularity of prescription				**<0.001***		**<0.001***
	Regular	27276	50.5% (n=13788)		1	
	As Required	3669	32.8% (n=1205)		0.538 (0.495–0.586)	<0.001*
	Once-Only	266	22.2% (n=59)		0.319 (0.235–0.433)	<0.001*
	TTO	3295	29.5% (n=973)		0.436 (0.397–0.478)	<0.001*
Prescription status				**<0.001***		**0.005***
	Continued	30557	47.0% (n=14350)		1	
	Deleted	3949	42.4% (n=1675)		0.898 (0.832–0.968)	0.005*

Message factors 'Message associated with the prescription' and 'High-risk error' were excluded from the GEE owing to multicollinearity.
Categorical data reported as %(n), with p-value from Chi-Square test.
**Significant at p<0.05.*

Appendix 10 – Chi-Square and generalised estimating equation results for time to sign-off ≤ 48 hours review message

Considering: 1) Temporal; 2) Message and; 3) Prescription factors. The results from the GEE have been reported alongside the Chi Square to allow for comparisons. Chi analysis shown is before any exclusions as a result of zero numbers and multicollinearity.

1) Temporal factors

					Chi-Square Test		Generalised Estimated Equations	
					Time to Sign-Off ≤ 48 hours		Time to Sign-Off ≤ 48 hours	
		Total no. of messages	Median time to Sign-Off (hours)	p-value	No. signed off ≤ 48 hours %(n)	p-value	Odds Ratio (95% CI)	p-value
Day of the week review message assigned				**^{KW}<0.001***		**<0.001***		**<0.001***
	Monday	3715	23.2 (2.4–69.4)		67.7% (n=2515)		1	
	Tuesday	3494	23.3 (2.7–65.7)		68.9% (n=2409)		0.977 (0.877–1.088)	0.670
	Wednesday	3055	23.1 (2.2–52.7)		70.1% (n=2166)		1.104 (0.984–1.237)	0.091
	Thursday	2798	22.6 (2.0–96.1)		67.4% (n=1885)		0.856 (0.763–0.961)	0.008*
	Friday	2792	42.5 (1.6–96.5)		51.5% (n=1439)		0.439 (0.392–0.491)	<0.001*
	Sat/Sun	171	47.1 (4.7–72.6)		51.5% (n=88)		0.381 (0.268–0.542)	<0.001*
Hour of day review message assigned				**^{MW}<0.001***		**0.001***		**0.013***
	00:00-12:59	9909	23.3 (2.1–72.8)		66.5% (n=6590)		1	
	13:00-23:59	6116	23.5 (2.6–89.5)		64.0% (n=3912)		0.911 (0.846–0.981)	0.013*
Time taken to assign review message				**^{KW}<0.001***		**<0.001***		**<0.001***
	< 12 hours	4068	20.0 (1.2–48.2)		74.8% (n=3044)		1	
	12-23:59 hours	4587	22.4 (2.0–70.8)		68.1% (n=3122)		0.841 (0.758–0.934)	0.001*
	1-6 days	6105	25.5 (3.1–92.9)		61.1% (n=3733)		0.633 (0.572–0.701)	<0.001*
	7+ days	1265	50.8 (12.6–166.6)		47.7% (n=603)		0.424 (0.365–0.492)	0.001*

2) Message factors

					Chi-Square Test		Generalised Estimated Equations	
					Time to sign-off ≤ 48 hours		Time to sign-off ≤ 48 hours	
		Total no. of messages	Median time to sign-off (hours)	p-value	No. signed off ≤ 48 hours %(n)	p-value	Odds Ratio (95% CI)	p-value
Grade of pharmacist				**[KW]<0.001***		**<0.001***		**0.368**
	6	4889	25.5 (2.1–94.3)		61.2% (n=3000)		1	
	7	7611	22.4 (2.1–71.3)		67.7% (n=5154)		1.065 (0.972–1.167)	0.178
	8	3525	23.4 (2.4–71.8)		66.6% (n=2348)		1.068 (0.943–1.209)	0.300
Message assigned to a high-risk medicine				**[MW]0.003***		**0.07**		**0.713**
	No	11703	23.1 (2.1–73.4)		65.9% (n=7718)		1	
	Yes	4322	24.1 (2.7–75.4)		64.4% (n=2784)		0.982 (0.890–1.083)	0.713
Message relates to a high-risk error				**[MW]0.003***		**0.026***		#
	No	15398	23.3 (2.2–73.5)		65.7% (n=10117)	0.026*	#	#
	Yes	627	25.1 (2.9–96.5)		61.4% (n=385)		#	#
Message relates to medicines reconciliation				**[MW]<0.001***		**<0.001***		**<0.001***
	No	8272	24.3 (2.6–91.6)		62.6% (n=5176)		1	
	Yes	7753	22.4 (1.9–70.2)		68.7% (n=5326)		1.210 (1.110–1.319)	<0.001*
Message associated with prescription				**[MW]<0.001***		**<0.001***		#
	No	1793	21.8 (1.9–66.8)		70.4% (n=1263)		#	#
	Yes	14232	23.6 (2.2–75.1)		64.9% (n=9239)		#	#
Communication theme				**[KW]<0.001***		**<0.001***		**<0.001***
	Dose/Frequency	5073	23.2 (2.4–71.7)		67.0% (n=3398)		1	
	Contraindication	419	40.7 (2.9–120.0)		54.9% (n=230)		0.721 (0.579–0.899)	0.004*
	Drug Form/Route	902	22.6 (1.7–71.9)		68.1% (n=614)		1.139 (0.969–1.339)	0.116
	Drug Interaction	351	27.0 (2.9–120.2)		60.7% (n=213)		0.989 (0.777–1.261)	0.932
	Drug Selection	1177	23.2 (2.2–72.1)		65.8% (n=775)		1.119 (0.969–1.291)	0.126
	Drug Use/Administration	1885	23.6 (1.7–72.3)		65.0% (n=1226)		0.863 (0.764–0.974)	0.017*

	Logistics	231	27.0 (3.7–89.7)		60.2% (n=139)		0.957 (0.717–1.278)	0.767
	Omission	1851	21.7 (2.0–66.8)		70.6% (n=1307)		0.043 (0.938–1.159)	0.437
	Other	284	24.9 (2.7–117.9)		59.9% (n=170)		0.566 (0.418–0.766)	<0.001*
	Supporting Information	3852	23.8 (2.1–92.9)		63.1% (n=2430)		0.956 (0.872–1.048)	0.339
Profession of signed user				**^{KW}<0.001***		**<0.001***		**0.001***
	Pharmacist	6302	23.7 (0.7–91.7)		63.2% (n=3980)		1	
	Consultant	1091	22.2 (3.1–67.9)		69.6% (n=759)		1.203 (1.020–1.420)	0.028*
	Junior	6329	22.9 (2.7–70.9)		67.7% (n=4284)		1.159 (1.061–1.267)	0.001*
	SPR/NMP	2303	24.3 (4.2–78.2)		64.2% (n=1479)		0.976 (0.867–1.099)	0.690

3) Prescription factors

					Chi-Square Test		Generalised Estimated Equations	
					Time to sign-off ≤ 48 hours		Time to sign-off ≤ 48 hours	
		Total no. of messages	Median time to sign-off (hours)	p-value	No. signed off ≤ 48 hours %(n)	p-value	Odds Ratio (95% CI)	p-value
Speciality				**^{KW}<0.001***		**<0.001***		**<0.001***
	Medical Admissions	3501	20.5 (1.7–48.2)		74.8% (n=2619)		1	
	Critical Care and Burns	1099	23.9 (3.0–72.4)		66.1% (n=726)		0.954 (0.786–1.157)	0.630
	General Medicine	4147	24.9 (2.4–94.5)		62.0% (n=2570)		0.775 (0.681–0.883)	<0.001*
	General Surgery	690	23.0 (1.4–76.6)		64.1% (n=442)		0.807 (0.664–0.981)	0.031*
	Medical Specialities	4267	23.2 (2.2–72.4)		65.9% (n=2812)		0.809 (0.714–0.917)	0.001*
	Surgical Specialities	1421	23.9 (2.5–76.9)		63.8% (n=907)		0.735 (0.630–0.857)	<0.001*
	TNO	900	51.3 (19.3–167.5)		47.3% (n=426)		0.419 (0.349–0.502)	<0.001*
BNF category				**^{KW}<0.001***		**<0.001***		**<0.001***
	Cardiovascular	4336	24.8 (3.0–95.7)		61.5% (n=2668)		1	
	Central nervous system	3510	23.7 (2.3–78.1)		64.8% (n=2273)		1.256 (1.131–0.884)	<0.001*
	Endocrine	1360	21.4 (1.6–65.5)		70.4% (n=958)		1.323 (1.143–0.875)	<0.001*
	Eye, Ear, nose and oropharynx	334	22.6 (1.9–75.5)		65.0% (n=217)		1.138 (0.880–1.136)	0.325
	Gastrointestinal	1418	24.1 (2.5–90.1)		62.8% (n=890)		1.032 (0.896–1.116)	0.663
	Infection	1634	19.9 (1.3–47.7)		75.5% (n=1233)		2.062 (1.775–0.563)	<0.001*
	Malignant disease and immunosuppression	151	22.6 (2.6–66.6)		71.5% (n=108)		1.484 (0.998–1.002)	0.051
	Musculoskeletal and joint disease	369	23.3 (2.4–68.6)		68.0% (n=251)		1.416 (1.100–0.909)	0.007*
	Nutrition and blood	1502	24.2 (2.7–89.6)		62.6% (n=940)		1.022 (0.892–1.121)	0.756
	Obstetrics, gynaecology and	240	22.9 (2.5–66.1)		70.8% (n=170)		1.289 (0.953–1.049)	0.100

	urinary-tract disorders							
	Other	32	9.6 (0.5–42.3)		81.3% (n=26)		2.521 (0.912–6.969)	0.075
	Respiratory	1000	22.3 (1.4–71.2)		67.8% (n=678)		1.246 (1.058–1.468)	0.008*
	Skin	139	23.8 (2.5–81.7)		64.7% (n=90)		1.257 (0.856–1.843)	0.243
Regularity of prescription				**^{KW}<0.001***		**<0.001***		**<0.001***
	Regular	13788	23.7 (2.5–73.8)		65.2% (n=8994)		1	
	As required	1205	30.9 (3.7–119.9)		55.7% (n=671)		0.813 (0.780–0.935)	0.004*
	Once-only	59	1.8 (0.1–20.2)		96.6% (n=57)		11.077 (2.581–47.533)	0.001*
	TTO	973	2.1 (0.3–26.2)		80.2% (n=780)		2.818 (2.321–3.421)	<0.001*
Prescription status				**^{MW}<0.001***		**<0.001***		**<0.001***
	Continued	14350	24.0 (2.5–76.2)		64.1% (n=9199)		1	
	Deleted	1675	5.3 (0.8–44.1)		77.8% (n=1303)		1.739 (1.520–1.989)	<0.001*

Message factors 'Message associated with the prescription' and 'High-risk error' were excluded from the GEE owing to multicollinearity.
Categorical data reported as %(n), with p-value from Chi-Square test. Continuous data reported as: median (lower quartile, upper quartile, with p-value from Mann-Whitney (MW) or Kruskal Wallis (KW) test.
**Significant at p<0.05.*
Profession of person signing off the message was excluded from the analysis since there is no profession for messages that were not signed-off.

Appendix 11 – Chi-Square and generalised estimating equation results for action as requested of review messages

Considering: 1) Temporal; 2) Message and; 3) Prescription factors. The results from the GEE have been reported alongside the Chi Square to allow for comparisons. Chi analysis shown is before any exclusions as a result of zero numbers and multicollinearity.

1) Temporal factors

			Chi-Square		Generalised Estimating Equations	
			Actioned as requested		Actioned as requested	
		Total no. of messages	Number actioned %(n)	p-value	Odds Ratio (95% CI)	p-value
Day of the week review message assigned				**0.037***		**0.073**
	Monday	2314	35.7% (n=826)		1	
	Tuesday	2111	37.8% (n=797)		1.078 (0.945–1.229)	0.263
	Wednesday	1828	34.6% (n=633)		0.923 (0.804–1.060)	0.256
	Thursday	1821	36.9% (n=672)		1.071 (0.932–1.231)	0.332
	Friday	1784	34.2% (n=611)		0.930 (0.808–1.070)	0.309
	Sat/Sun	133	27.1% (n=36)		0.754 (0.490–1.158)	0.197
Hour of day review message assigned				**0.015***		**0.847**
	00:00-12:59	6333	36.7% (n=2322)		1	
	13:00-23:59	3658	34.3% (n=1253)		0.991 (0.903–1.087)	0.847
Time taken to assign review message				**<0.001***		**<0.001***
	< 12 hours	2715	31.2% (n=846)		1	
	12-23:59 hours	2965	39.5% (n=1171)		1.335 (1.186–1.503)	<0.001*
	1-6 days	3633	36.8% (n=1336)		1.241 (1.097–1.404)	0.001*
	7+ days	678	32.7% (n=222)		1.099 (0.896–1.347)	0.364

2) Message factors

			Chi-Square		Generalised Estimating Equations	
			Actioned as requested		Actioned as requested	
		Total no. of messages	Number actioned %(n)	p-value	Odds Ratio (95% CI)	p-value
Grade of pharmacist				**<0.001***		**<0.001***
	6	2746	31.9% (n=876)		1	
	7	5145	38.1% (n=1962)		1.203 (1.061–1.365)	0.004*
	8	2100	35.1% (n=737)		1.379 (1.182–1.607)	<0.001*
Message assigned to a high-risk medicine				**0.019***		**0.012***
	No	7411	36.4% (n=2701)		1	
	Yes	2580	33.9% (n=874)		0.848 (0.745–0.964)	0.012*
Message relates to a high-risk error				**<0.001***		#
	No	9406	35.3% (n=3316)		#	#
	Yes	585	44.2% (n=259)		#	#
Message relates to medicines reconciliation				**<0.001***		**<0.001***
	No	5498	30.3% (n=1664)		1	
	Yes	4493	42.5% (n=1911)		1.278 (1.144–1.428)	<0.001*
Communication theme				**<0.001***		**0.014***
	Dose/Frequency	8628	36.4% (n=3140)		1	
	Drug Form/Route	1056	33.9% (n=358)		1.099 (0.941–1.285)	0.233
	Drug Use/Administration	254	25.2% (n-64)		0.680 (0.475–0.973)	0.035*
	Logistics	53	24.5% (n=13)		1.936 (0.985–3.807)	0.056

3) Prescription factors			Chi-Square		GEE	
			Actioned as requested		Actioned as requested	
		Total no. of messages	Number actioned %(n)	p-value	Odds Ratio (95% CI)	p-value
Speciality				**<0.001***		**<0.001**
	Medical Admissions	2555	44.9% (n=1146)		1	
	Critical Care and Burns	568	38.0% (n=216)		0.921 (0.718–1.180)	0.515
	General Medicine	2207	37.3% (n=820)		1.038 (0.884–1.218)	0.651
	General Surgery	561	32.8% (n=184)		0.750 (0.602–0.934)	0.010
	Medical Specialities	2783	29.1% (n=809)		0.706 (0.610–0.816)	<0.001*
	Surgical Specialities	831	25.9% (n=215)		0.585 (0.483–0.709)	<0.001*
	TNO	486	38.1% (n=185)		1.192 (0.945–1.504)	0.139
BNF category				**<0.001***		**<0.001**
	Cardiovascular	2368	37.5% (n=888)		1	
	Central nervous system	2499	36.2% (n=905)		1.162 (1.024–1.320)	0.020*
	Endocrine	765	41.8% (n=320)		1.132 (0.944–1.356)	0.180
	Eye, Ear, nose and oropharynx	241	34.4% (n=83)		0.872 (0.646–1.176)	0.369
	Gastrointestinal	1197	26.1% (n=312)		0.771 (0.648–0.917)	0.003*
	Infection	1151	37.8% (n=435)		1.246 (1.048–1.482)	0.013*
	Malignant disease and immunosuppression	81	34.6% (n=28)		0.918 (0.555–1.519)	0.740
	Musculoskeletal and joint disease	223	38.6% (n=86)		1.204 (0.888–1.632)	0.232
	Nutrition and blood	710	36.2% (n=257)		0.815 (0.677–0.981)	0.030*
	Obstetrics, gynaecology and urinary-tract disorders	130	36.9% (n=48)		0.892 (0.603–1.320)	0.568
	Other	9	0.0% (n=0)		#	#
	Respiratory	540	36.7% (n=198)		0.906 (0.734–1.119)	0.358
	Skin	77	19.5% (n=15)		0.546 (0.297–1.005)	0.052

Mode of prescription				**<0.001***		**<0.001***
	Regular	8030	41.5% (n=3330)		1	
	As required	1315	18.6% (n=245)		0.374 (0.317–0.442)	**<0.001***
	Once-only	70	0.0% (n=0)		#	**#**
	TTO	576	0.0% (n=0)		#	**#**
Prescription status				**<0.001***		
	Continued	8736	40.8% (n=3566)		#	
	Deleted	1255	0.7% (n=9)		#	#

Message factor 'Message relates to a high-risk error' were excluded from the GEE owing to multicollinearity.
Message factor 'Messages associated with prescription' and prescription factor Mode 'TTO' and 'Once-only' were excluded owing to 'zero' numbers that were correctly actioned. Message factor Communication theme 'Contraindication', 'Drug Interaction', 'Drug Selection', 'Omission', 'Other' and 'Supporting Information were removed from the analysis owing to zero numbers.
Chi Square analysis based on numbers of review messages prior to exclusions.Prescription factor BNF Category 'Other' was deleted owing to low numbers.
Categorical data reported as %(n), with p-value from Chi-Square test
Significant at p<0.05

Appendix 12 – Chi-Square and generalised estimating equation results for time to action as requested ≤ 24 hours of review messages

Considering: 1) Temporal; 2) Message and; 3) Prescription factors. The results from the GEE have been reported alongside the Chi Square to allow for comparisons. Chi analysis shown is before any exclusions as a result of zero numbers and multicollinearity.

1) Temporal factors

					Chi-Square		Generalised Estimating Equations	
					Time to Action as requested ≤ 24 hours		Time to action as requested ≤ 24 hours	
		Total no. of messages	Median time to Sign-Off (hours)	p-value	No. correctly actioned ≤ 24 hours %(n)	p-value	Odds Ratio (95% CI)	p-value
Day of the week review message assigned				**[KW]0.053**		**<0.001***		**<0.001***
	Monday	826	20.2 (2.2–48.2)		59.0% (n=487)		1	
	Tuesday	797	22.1 (2.4–47.3)		56.5% (450)		0.831 (0.676–1.022)	0.079
	Wednesday	633	22.3 (2.4–48.0)		58.5% (n=370)		0.948 (0.757–1.187)	0.640
	Thursday	672	21.4 (2.3–45.4)		60.4% (n=406)		0.970 (0.779–1.208)	0.785
	Friday	611	22.8 (1.9–94.1)		51.1% (n=312)		0.663 (0.530–0.828)	<0.001*
	Sat/Sun	36	37.3 (10.1–54.1)		30.6% (n=11)		0.276 (0.130–0.585)	0.001*
Hour of day review message assigned				**[MW]<0.001***		**0.373**		**0.714**
	00:00-12:59	2322	21.6 (2.2–49.2)		57.5% (n=1335)		1	
	13:00-23:59	1253	22.1 (3.1–69.1)		55.9% (n=701)		0.973 (0.840–1.127)	0.714
Time taken to assign review message				**[KW]<0.001***		**<0.001***		**0.001***
	< 12 hours	846	21.6 (3.1–44.2)		61.0% (n=516)		1	
	12-23:59 hours	1171	19.0 (1.9–45.6)		60.7% (n=711)		1.036 (0.856–1.254)	0.719
	1-6 days	1336	22.7 (2.2–69.8)		53.7% (n=717)		0.836 (0.686–1.019)	0.076
	7+ days	222	40.3 (3.4–139.4)		41.4% (n=92)		0.559 (0.402–0.777)	0.001*

2) Message factors

					Chi-Square Test		Generalised Estimated Equations	
					Time to action as requested ≤ 24 hours		Time to action as requested ≤ 24 hours	
		Total no. of messages	Median time to sign-off (hours)	p-value	No. correctly actioned ≤ 24 hours %(n)	p-value	Odds Ratio (95% CI)	p-value
Grade of pharmacist				**[KW]<0.001***		**<0.001***		**0.002***
	6	876	25.2 (3.8–78.1)		47.5% (n=416)		1	
	7	1962	20.4 (2.2–47.5)		60.7% (n=1191)		1.408 (1.167–1.698)	<0.001
	8	737	20.2 (1.7–51.4)		58.2% (n=429)		1.293 (1.013–1.651)	0.039
Message assigned to a high-risk medicine				**[MW]0.028***		**0.112**		**0.707**
	No	2701	22.1 (2.4–57.1)		56.2% (n=1518)		1	
	Yes	874	20.4 (1.9–48.2)		59.3% (n=518)		1.040 (0.846–1.279)	0.707
Message relates to medicines reconciliation				**[MW]0.349**		**0.125**		**0.859**
	No	1664	24.7 (3.4-75.5)		55.6% (n=925)		1	
	Yes	1911	23.1 (3.2-68.3)		58.1% (n=1111)		1.016 (0.852–1.212)	0.859
Communication theme				**[KW]0.224**		**0.277**		**0.581**
	Dose/Frequency	3140	21.6 (2.4–51.6)		57.4% (n=1802)		1	
	Drug Form/Route	358	22.8 (1.4–72.0)		55.0% (n=197)		0.992 (0.775–1.268)	0.992
	Drug Use/Administration	64	24.2 (3.5–52.7)		50.0% (n=32)		0.946 (0.551–1.623)	0.839
	Logistics	13	51.4 (22.6–96.5)		38.5% (n=5)		0.453 (0.148–1.386)	0.165

3) Prescription factors

					Chi-Square Test		Generalised Estimated Equations	
					Time to action as requested ≤ 24 hours		Time to action as requested ≤ 24 hours	
		Total no. of messages	Median time to sign-off (hours)	p-value	No. correctly actioned ≤ 24 hours %(n)	p-value	Odds Ratio (95% CI)	p-value
Speciality				**^{KW}<0.001***		**<0.001***		**0.093**
	Medical Admissions	1146	19.9 (2.2–36.0)		63.8% (n=731)		1	
	Critical Care and Burns	216	19.7 (0.7–72.6)		56.0% (n=121)		0.831 (0.585–1.180)	0.301
	General Medicine	820	23.8 (2.2–70.8)		51.6% (n=423)		0.832 (0.658–1.052)	0.124
	General Surgery	184	22.1 (1.9–73.4)		52.2% (n=96)		0.767 (0.551–1.068)	0.116
	Medical Specialities	809	20.4 (2.2–48.0)		58.6% (n=474)		0.857 (0.684–1.073)	0.179
	Surgical Specialities	215	24.0 (4.1–90.2)		50.7% (n=109)		0.714 (0.519–0.981)	0.038
	TNO	185	28.3 (7.2–110.9)		44.3% (n=82)		0.598 (0.422–0.848)	0.004
BNF category				**^{KW}<0.001***		**<0.001***		**0.001***
	Cardiovascular	888	23.0 (3.4–68.8)		53.7% (n=477)		1	
	Central nervous system	905	21.4 (1.9–54.5)		57.2% (n=518)		1.205 (0.987–1.471)	0.067
	Endocrine	320	21.7 (2.6–48.1)		59.1% (n=189)		1.158 (0.879–1.527)	0.297
	Eye, Ear, nose and oropharynx	83	24.5 (4.1–97.4)		45.8% (n=38)		0.806 (0.499–1.302)	0.378
	Gastrointestinal	312	23.2 (2.6–75.7)		52.2% (n=163)		0.941 (0.709–1.249)	0.674
	Infection	435	6.0 (1.2–26.4)		69.2% (n=301)		2.055 (1.546–2.732)	<0.001*
	Malignant disease and immunosuppression	28	23.4 (2.3–51.0)		53.6% (n=15)		0.958 (0.442–2.075)	0.913
	Musculoskeletal and joint disease	86	22.0 (2.2–48.2)		57.0% (n=49)		1.142 (0.713–1.830)	0.580
	Nutrition and blood	257	21.4 (3.4–51.8)		58.0% (n=149)		1.116 (0.830–1.500)	0.467

	Obstetrics, gynaecology and urinary-tract disorders	48	23.4 (2.4–44.4)		52.1% (n=25)		0.921 (0.504–1.682)	0.788
	Respiratory	198	24.0 (2.4–69.6)		52.0% (n=103)		0.893 (0.645–1.238)	0.498
	Skin	15	19.2 (2.2–54.0)		60.0% (n=9)		1.493 (0.495–4.501)	0.477
Mode of prescription				**^{MW}0.090**		**0.019**		**0.468**
	Regular	3330	21.6 (2.2–51.6)		57.5% (n=1914)		1	
	As required	245	24.2 (2.2–90.2)		49.8% (n=122)		0.896 (0.666–1.206)	0.468
Prescription status				**^{MW}0.001***		**#**		**#**
	Continued	14350	#				#	#
	Deleted	1675	#				#	#

Message factor 'Message relates to a high-risk error' were excluded from the GEE owing to multicollinearity.
Message factor 'Messages associated with prescription' and prescription factor Mode 'TTO' and 'Once-only' were excluded owing to 'zero' numbers that were correctly actioned. Message factor Communication theme 'Drug Interaction' and 'Other' were excluded from the analysis owing to zero numbers.
Message factor Communication theme 'Contraindication', 'Drug Selection', 'Omission' and 'Supporting Information were removed from the analysis owing to low numbers.
Prescription factor BNF Category 'Other' was deleted owing to low numbers.
Categorical data reported as %(n), with p-value from Chi-Square test
Significant at p<0.05

Appendix 16 – Summary of publications from the research

Chapters or sections of the thesis have been disseminated through publication in peer-reviewed journals. These have been cited at the beginning of the relevant chapters and are summarised below. Note that during the period of undertaking this research, I had a change of surname from 'Thomas' to 'Pontefract'.

- Thomas, S. K. and Coleman, J. J. (2012). The impact of computerised physician order entry with integrated clinical decision support on pharmacist–physician communication in the hospital setting: a systematic review of the literature. *European Journal of Hospital Pharmacy: Science and Practice*, 19 (3): 349-354.
- Thomas, S. K., McDowell, S. E., Hodson, J., et al. (2013) Developing consensus on hospital prescribing indicators of potential harms amenable to decision support. *British Journal of Clinical Pharmacology*, 76 (5): 797-809.
- Pontefract, S. K., Hodson, J., Marriott, J. F., et al. (2016) Pharmacist-Physician Communications in a Highly Computerised Hospital: Sign-Off and Action of Electronic Review Messages. *PLoS ONE,* 11 (8): e0160075.
- NHS England: Office of the Chief Pharmaceutical Officer, M. D. (2016). Transformation of seven day clinical pharmacy services in acute hospitals. Case Study: Pharmacist-physician communication across the working week. NHS England, London.