UNIVERSITY OF BIRMINGHAM

Electronic Prescribing Errors in Secondary Care Settings: Their Incidence, Causes and Strategies for Reduction

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A thesis submitted to the University of Birmingham for the degree of Doctor of Philosophy

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List of Abbreviations

ADE[s] = Adverse Drug Event and Adverse Drug Events

ADR[s] = Adverse Drug Reaction and Adverse Drug Reactions

BNF = British National Formulary

CDSS = Computerised Decision Support System

CIT = Critical Incident Technique

CPOE = Computerised Physician or Prescriber Order Entry

df = Degrees of freedom

DH = Department of Health

EHR = Electronic Health Record

EMR = Electronic Medical Record

E-prescribing and e-prescribing = Electronic Prescribing

E-prescription and e-prescription = Electronic Prescription

GP= General Practitioner

HIT= Health Information Technology

IOM = Institute Of Medicine

IQR = Interquartile Range

IT= Information technology

NHS = National Health System

NPfIT= National Programme for Information Technology

NRLS = National Reporting and Learning System

OR = Odds Ratio

PADE[s] = Preventable adverse drug event[s]

PICS = Patient Information and Communication System

PSIs = Patient safety incidents

UHBFT= University Hospitals Birmingham Foundation Trust

UK= United Kingdom

US= United States of America

WHO = World Health Organisation

Abstract

Electronic prescribing systems (EPS) may be considered to enhance safe prescribing compared to paper-based prescribing systems. This thesis examined EPS safety, including in non-medical prescribers, in three studies.

Firstly, a systematic review and meta-analysis examined the impact of EPS on the incidence of prescribing errors in hospital settings. EPS was associated with a reduction in prescribing errors based on a random effects model odds ratio (OR=0.26, 95% CI, 0.14 to 0.42, $p<0.00001$).

Secondly, prescribing errors detected and reported in hospital pharmacist interventions were examined. Errors were identified in 1.1% (95% CI 1.1 to 1.2%) of prescribed items. Most errors were considered significant (68.5%). Over half (56%) of errors occurred at the admission stage.

Finally, a qualitative examination of semi-structured interviews was conducted with 23 medical and non–medical prescribers in a hospital. Prescribers described multiple contributory factors to electronic prescribing errors, including human factors and human-computer interactions. Prescribers' perceptions of the benefits of EPS were clear, although concerns about overreliance on EPS and system complexity remained. Prescribers had useful suggestions to increase prescribing safety.

In combination, the three branches of this thesis show EPS is an effective tool, and provides insights that can potentially optimise safe prescribing, including tailoring to end-user requirements.

Declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or institute of learning.

Dedication

I would like to dedicate this thesis to my late father, Abdullah Alshahrani, who passed away while I was writing this thesis.

Acknowledgment

I would like to express my sincere gratitude to my supervisors Professor John Marriott and Dr Anthony Cox for the continuous support of my Ph.D. study and related research, for their patience, motivation, and immense knowledge. Their guidance helped me in all the time of research and writing of this thesis. I could not have imagined having better supervisors for my PhD study. I am indebted to them more than they know for nurturing my research skills and critical thinking.

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Abstracts related to this thesis

Alshahrani, F., Marriott, J. F., Cox, A. R. 'The impact of electronic prescribing systems on the incidence of prescribing errors within in-patients settings' Pharmacy Practice (Poster discussion forum at the Royal Pharmaceutical Society conference, September, 2015; Birmingham, UK).

Alshahrani, F., Marriott, J. F., Cox, A. R. 'Perceived causes of and contribution factors of electronic prescribing errors in hospital inpatients' Drug Safety (Poster discussion forum at U21 Health Sciences Doctoral Forum, 18th September, 2017 , University of Johannesburg, Johannesburg South Africa).

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Alshahrani, F., Marriott, J. F., Cox, A. R. 'E-prescribing: A qualitative study of socio-technical issue arising from medical and non-medical prescribers in an English hospital' (Poster discussion forum at the International Social Pharmacy Workshop, 23rd – 26th July, 2018, Leuven, Belgium).

Alshahrani, F., Marriott, J. F., Cox, A. R. Reducing Prescribing Errors Associated With In-Patient Electronic Prescribing Systems: An Investigation Of Pharmacist Interventions (Poster discussion forum at 18th Annual Meeting of the International Society of Pharmacovigilance, 11th - 14th November, 2018, Geneva, Switzerland).

1 Chapter 1: Introduction

1.1 Background

Medications account for the majority of interventions in long-term medical conditions (National Institute for Health and Care Excellence, 2015). The decision to prescribe a medicine includes balancing the perceived benefits with the potential harms. These drug-related problems can include risks such as adverse drug reactions (ADRs), drug-drug interactions, and exposure to medication errors.

In England, 850,000 inpatient admissions are estimated to be a result of drug related problems, with an associated cost of increased mortality and £2 billion additional bed-days (Department of Health, 2000, Wu et al., 2010). Drug-related problems may occur even when a prescription is appropriate (for example, overdoses, adverse drug reactions or allergies), although some of these problems may be termed "preventable" if there are questions as to the appropriateness of the medication choice.

Prescribing, dispensing, administration and monitoring are stages that make up the complex process of medication use, and involve different healthcare professionals and others over different geographical locations, thereby introducing the possibility for error at each stage. Any error that occurs at any of these stages and causes harm to a patient is considered preventable. At any stage of the medication use process, errors can be introduced. Such errors can be minor and lead to no harm, ranging to errors that are major in nature leading serious harm and death, and associated costs, healthcare or otherwise

Patient safety improvement is a key aim for most health systems (The Health Foundation, 2012), and medication errors have been identified as one of the major avoidable causes of morbidity and mortality (Department of Health, 2000, Kohn et al., 1999). It was estimated by the National Patient Safety Agency in 2007 that the cost of preventable medication harm in the NHS is more than £750 million each year (National Patient Safety Agency, 2007).

This thesis examines the issue of drug-related problems, specifically prescribing errors within an electronic prescribing system, through a systematic review, a quantitative study of

pharmacists' clinical interventions, and a qualitative study of both medical and non-medical prescribers.

1.2 Safety and quality in healthcare

1.2.1 Patient Safety

When a healthcare professional treats a patient, the primary objective is to help the patients rather than cause any kind of harm. This is evident as embodied in the basic Hippocratic Oath; *"First, do no harm,"* a popular phrase amongst nursing and medical professionals, dating back to as early as the 1860s (Nightingale, 1863). Unfortunately, healthcare can cause patient harm and there have been records of patient harm in many cases, sometimes dues to institutional wide problems. For example, the Mid Staffordshire National Health Service (NHS) Foundation Trust scandal led to hundreds of patients dying through poor care delivered by professionals (Holmes, 2013). Healthcare which is detrimental to patient health is defined as "iatrogenic", meaning harm caused by the care or treatment provided. However, the term "harm" would be more appropriate owing to the intentions of those responsible (Reynard, 2012).

Preventing patient death or harm is one of the six dimensions of healthcare quality, as stated by The Institute of Medicine (IOM) (2001). Furthermore, the phrase "patient safety" has been defined as '*The avoidance, prevention and amelioration of adverse outcomes or injuries stemming from the process of healthcare'* (Vincent, 2012). In other words, this definition recognizes that the risks are bound to occur when delivering healthcare and that quality and preventative measures should be undertaken when delivering care.

In recent years, patient safety has become an important tenet of government healthcare policies in both the UK, US and European countries. In the UK, a number of government publications about patient safety issues and avoidable harm at health care settings have been published, such as " *An Organisation with a Memory"* in the UK in 2000 (Department of Health, 2000) and in the US "To Err is Human" was published by the Institute of Medicine (IOM) in 1999 (Kohn et al., 1999). The body of evidence started to emerge and can be traced back to studies from previous decades (Brennan et al., 1991, Leape et al., 1991, Vincent et al., 2001). These studies exposed the scale of patient harm in healthcare settings and hospitals. Before these publications, patient safety and iatrogenic scenarios were not widely acknowledged and patient

safety issues remained largely neglected (World Health Organization, 2004). However, there was still little to no public/ professional outcry when more iatrogenic cases were reported during the 1990's (Vincent, 2012). This could have been down to numerous reasons; fear of litigation, clinician awareness and limited patient / public understanding (Gallagher et al., 2006, O'connor et al., 2010). However, the release of these publications elicited an increase in patient safety literature. This increased awareness led to reductions in preventable harm in both the US and UK (Emslie et al., 2010). It also led to the development of patient safety organizations across UK, Canada and Australia (Emslie et al., 2010, World Health Organization, 2004). Preventative measures for patient safety have been increased, but critics argue that progress has been slow (Vincent and Amalberti, 2016).

1.2.2 Clinical governance and risk management

The National Health Service (NHS), UK, created clinical governance in the late 1990s to promote patient safety, quality of care and services (Scally and Donaldson, 1998). The governance strategy was first implemented in the business field on a trial basis to identify flaws and failures which can be improved upon to provide standard services. Scally and Donaldson (1998) defined clinical governance as *"A system through which NHS organisations assumes accountability for promoting continuous improvements in the quality of their services and safeguarding high standards of care through the creation of an enabling environment where excellence in clinical care will flourish.".*

Medical advancements and complexity in practices created an increased awareness and the need for all hospitals and the entire system to imbibe strategies that will promote consistency in providing high quality care to everyone (Kohn et al., 1999). Therefore, clinical governance is a comprehensive multi system approach integrated together towards achieving high quality healthcare (Figure 1.1).

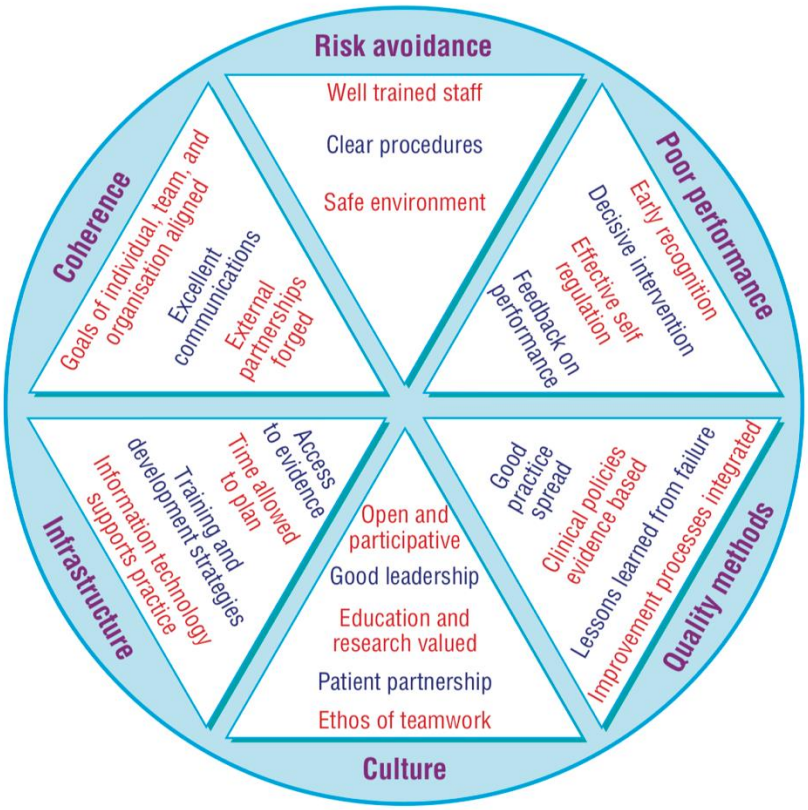


Figure 1.1. Integrating multisystem approaches of Clinical Governance (Scally and Donaldson, 1998).

Furthermore, four aspects of healthcare quality were recommended by the World Health Organization (1983) which included professional performance, efficiency, risk management, and patients' satisfaction with the service provided. Similarly in 2001, the IOM reported six dimensions of quality in healthcare which encompassed the four earlier recommendations by the WHO with mild modifications and included; (effectiveness, efficiency, safety, and patient-centeredness) in addition to timeliness and equitability (Corrigan, 2005).

The Department of Health (DH), UK, in 1998 also published an article about the quality of care in the new NHS where it emphasised that clinical governance was a very important strategy required to promote continuous improvement in the NHS in order to optimise quality assurance of clinical decisions. The report outlined the key activities and responsibilities required to achieve an effective clinical governance system of which the notable pathways included conducting quality improvement activities (e.g. clinical audit), monitoring of clinical care (e.g. electronic patient records), implementing clinical guidelines (e.g. National Institute for Health and Care Excellence guidance), supporting and applying evidence-based medicine,

professional development, assessing and managing risk (e.g. critical incident reporting), and making clear lines of responsibility and accountability (Department of Health, 1998).

Therefore, risk management was unanimously recommended by the WHO, IOM, and DH as a significant approach required to achieve effective clinical governance. Risk management was defined as *"self-protective activities meant to prevent real or potential threats of financial loss due to accident, injury, or medical malpractice."* (Kraman and Hamm, 1999).

Dickson (1995) identified three main principles of risk management namely; identify a risk (which is achieved through the combination of different approaches), analyse their impacts, and control/manage them (through minimization of health and financial implications).

Risk management was introduced into the health sector owing to litigation compensation costs. It became a useful strategy required to create several approaches targeted at reducing the incidence of harm, identification and prompt reporting of adverse events, as well as dignified care for patients who were harmed or affected in the incident. Therefore, in addition to reducing the rates of compensation and risk claims as well as financial losses through those claims, legal suits and compensation, clinical risk management aims at reducing the incidence of preventable adverse events and reduce the number of patients affected, improving health and safety with grossly reduced financial implications (Vincent and Moss, 1995). Also, several reporters observed that the creation of an open and participative culture in a healthcare institution is one of the major approaches to clinical governance in order to maintain standard practices (Scally and Donaldson, 1998).

1.2.3 Safety culture

The two reports *'To Err is* Human' in the US and *'An organisation with a memory'* in the UK, reports have both instigated international discussions on the role of organisational culture in the prevalence of preventable adverse events in health institutions. Experiences from other critical domains such as those from the aviation and nuclear industry have influenced the suggestion of a new perception of human error to healthcare, linking it to be either system based or an organisational perspective (Helmreich, 2000, Reason, 2000, Sexton et al., 2000). The system-based approach is a recommendation which deals with proactive strategies involving systematic ways of reporting errors and adverse events, which serves as an

alternative approach to the reactive strategies used in error management, identification and control of the latent conditions.

The major recommendations from the Berwick report (2013) stated that if patient safety in England must be achieved, then the dominant culture of blame attitudes, fear and refusal to report error, control-oriented, and requirement-driven management must be avoided. Berwick (2013) instead, advised the NHS to create an atmosphere and culture of trust in the scheme, show appreciation to members, maintain transparency and openness, imbibe teamwork, get members to be involved and develop continuous learning and improvement updates for sustainability of standard practices noting that this culture would improve and promote patient safety. Berwick (2013) further noted that:

> *"Culture will trump rules, standards and control strategies every single time, but to achieve a vastly safer NHS, depends mainly on changing the safety culture rather than new regulatory regime".*

Major efforts and developments put in place to establish a safety culture in the UK started in the early 1990s. The Health and Safety Commission, UK (1993) released safety culture reports, which addressed the need to create and promote a safety culture and defined it as:

> *"The product of individual and group values, attitudes, perceptions, competencies, and patterns of behaviour which determines the commitment, style and proficiency of an organisation's health and safety management."*

More steps towards a safety culture in the NHS organisation followed the reports of the Health and Safety Commission, (1999), with attempts to change the dominant blame culture among personnel to a culture of trust and openness in the NHS (Department of Health, 2000, National Patient Safety Agency, 2004). Despite a view that some culture had changed, serious failures were noted in Mid Staffordshire (UK) as reported by Francis (2013) and Berwick (2013), which still noted in their independent findings that the blame culture was still prevalent in the NHS. To further strengthen the progress, the DH (2000) adopted four key subcomponents of a positive safety culture as discovered from the research of Reason (1997). These sub components included:

- Develop a reporting culture where staff assume responsibility and are ready to report their errors. Accurate analysis of the data and feedback to the affected staff are essential to explain what actions being taken to control, manage and prevent future occurrence.
- Develop a transparent culture of trust which motivates staff to provide any useful information related to safety, which also holds them accountable in any actions breaching ethics and codes of conduct.
- Create a flexible culture respecting frontline staff skills and abilities, also allowing task experts to provide their opinion and suggestions where and when necessary.
- Create a learning culture where staff are motivated to learn and build their confidence and competencies by creating avenues where they learn from their errors, and implement major reforms where needed.

Implementing a safety culture to improve patient safety seems obviously beneficial, however it is important to gather evidence to support this practice. Singer et al. (2009) assessed the impact of safety culture on hospitals' performance using patient safety indicators derived from the Agency for Healthcare Research and Quality (AHRQ) indicators (2007) in the United States. A questionnaire was distributed to 35,006 healthcare staff in 91 hospitals using a 38-question survey on safety-related topics. Findings from their research showed that higher levels of safety culture had a positive correlation with higher safety performance (IRR=1.034, $P<0.05$). They also reported that hospitals with high staff reporting problems owing to fear of shame (IRR=1.050, $P<0.05$) or blame (IRR=1.013, $P<0.01$) following full analysis were associated with lower rates of safety performance. The study had a reasonable response rate of 52%.

Safety cultures can be hard to establish. Changes can occur in the wake of medication errors or training, but staff attitudes and behaviours may not change if staff consider learning as a one-off event. Therefore, there is need to incorporate an active learning approach to medication errors into the daily staff work flow. In healthcare organisations, changes in clinical practice occur following a safety issue, and are then abandoned when new priorities emerge or leadership goals changes. It is therefore important that any changes are actioned in a reasonable time and are sustainable, so they can be put in place or utilised when the need arises (NPSA, 2004).

1.2.4 Safety models

Safety models were introduced to promote the understanding and analysis of the nature and causes of healthcare-related errors in the health organisation as a preventive strategy. One such human error model, developed by James Reason in 1990, described the problem using two approaches; the person approach (active failures) and the system approach (latent failures) (Reason, 1990). The person approach divides the psychologically unsafe human acts into unintended and intended actions. Unintended unsafe actions occur as a result of poor planning process prior to executing the project while the intended unsafe actions occur when inappropriate or incorrect plans are executed after several good planning steps.

Reason (1990), furthermore, pointed out that the unintended actions are generally skill-related and can exist in the form of a slip (when a clinician in the process of carrying out an intended action, mistakenly does something else which is considered to be wrong) or lapses (caused by memory failure or unconscious mental errors). The slips described by Reason (1990) were further divided into capture and description error by Leape (1994). The capture errors occur in events where a more common action is executed instead of a similar but less familiar one: for example, when a commonly used drug is dispensed instead of the prescribed look-alike/sound-alike drug while description errors occur as a result of performing the right action on the wrong object such as administering the right drug but to the wrong patient. Leape (1994) also described two types of lapses. The first, known as associative activation errors where ideas are mentally associated. The second type of lapse is associated with activation errors resulting from temporary memory losses (e.g. initiating an action and forgetting it along the process owing to memory failure).

Reason (1990) also described the intended actions into two, firstly; mistakes which occurred owing to the wrong application of rules (rule-dependent) and secondly mistakes occurring owing to a deficit in knowledge or understanding (knowledge-based i.e. when a person is unaware of a committed error) and violations (such as intentional policy violation). Leape (1994) argued that rule-based errors can also result from the misperception of a situation or wrong application of knowledge or expertise. The knowledge-based errors have been related to four habits of thought. Biased memory which is the first habit, involves a situation whereby decisions are made based on familiar patterns that exist in the memory (e.g. overgeneralising a

rare case treatment). The second habit is the availability heuristic habit which involves using information that directly comes from the mind first. The third habit was confirmation bias, which involves a process of finding evidence that supports an already existing perception while ignoring any data that is contradicting. The final habit is overconfidence where there is a strong likelihood of choosing a certain action while focusing only on the evidence in favour of the chosen action (Leape, 1994).

An important part of the system approach to errors described by Reason (1990) is the concept of latent failures. Latent failures occur when strategic decisions made by the decision makers within an organisation (e.g. directors or managers) introduce potentially risk inducing situations into a work system. The system wide decisions can provide conditions where errors can arise (e.g. pressure, time and fatigue) leading to prolonged problems in the system. The latent failures or conditions can remain undetected for several years before leading to local prompts and active failures which degenerate into incidents causing harm. Reason (1990) in the Swiss Cheese model, elucidates how these conditions can create holes within the defence layer of a system through which human errors can travel to cause serious incidents. Figure 1.2 provides a summary of this human error model.

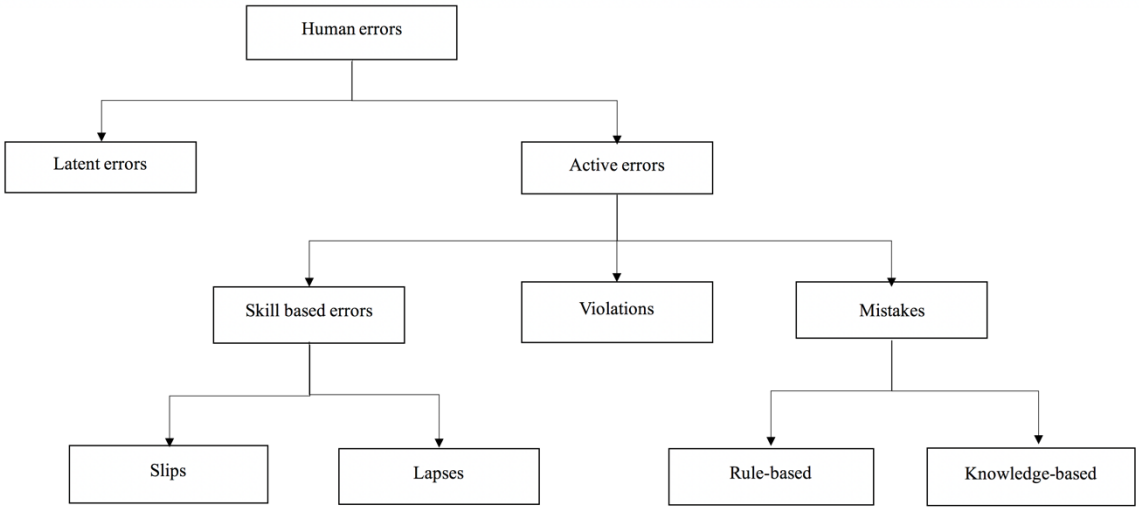


Figure 1.2. The Reason Model of Human Error (based on Reason, 1990).

Vincent et al. (1998) further designed a framework to analyse incidents in healthcare institutions. This framework established a hierarchy of factors which could affect clinical practices. The latent factors, regarded as the most influential encompassed factors related to

institutional context and organisational / management factors. These factors included; under staffing levels, poor facilities and working conditions, and lack of support which creates conditions which make staff vulnerable to committing errors.

1.2.5 Incidence of patient safety incidents

Patient safety incidents (PSIs) affect a significant number of patients who seek medical care within health care institutions. The effects of such incidents can often lead to undesirable clinical and financial consequences. The IOM report 'To Err is Human' (Kohn et al., 1999) reported that adverse events were experienced in about 2.9% to 3.7% of hospital admissions of which half of such incidents could be prevented. The report also noted that an estimated 44,000 to 98,000 American patients die per annum owing to preventable adverse events. These statistics were extracted from the data linked to two large studies which evaluated the annual number of hospital admissions in the US in 1997. The reports further revealed that the total national cost implications of these preventable PSIs were estimated to be between $17 billion and $29 billion. Subsequently, James (2013) noted that the number of severe preventable adverse events and deaths was estimated to be a minimum of 2 million severe injuries and 210,000 deaths occur annually in the US. These figures were based on the extrapolation of a weighted average rate involving four large previous studies which utilised the Institute for Healthcare Improvement (IHI) Global Trigger Tool (Griffin and Resar, 2009) to evaluate and detect PSIs from hospital medical records. The number of incidents which were not detected by the Global Trigger Tool was estimated to be 4 million serious injuries and 440,000 deaths occur every year owing to preventable PSIs.

Similarly, Wilson et al. (1995) assessed the quality of Australian healthcare by evaluating the medical records of 14,179 patients who were admitted to 28 hospitals. Wilson and co-workers (1995) detected a PSI rate of 16.6% (n=2,302) of which half (8.3%) were regarded to be preventable. Out of the entire incidents, 13.7% (n=315) resulted in permanent harm while 4.9% (n=112) resulted in death. The World Health Organisation (WHO, 2013) also reported that PSIs occur in every 8–12% of hospitalised patients in the European Union (EU). WHO further stated that 23% of the EU citizens reported claims of PSI experiences in the past, 18% claim to have experienced a serious PSI in a hospital, while about 11% claim they have suffered incidents owing to a wrong medication prescribed. WHO suggested that since 50–70% of these PSIs are preventable, strategies to minimise the rate of these incidents in the EU would lead to

the prevention of more than 750,000 harmful PSIs per annum which would prevent 3.2 million hospitalisation days, and prevent 260,000 permanent disabilities prevent 95,000 deaths per annum.

The UK report 'An Organisation with a Memory' (Department of Health, 2000) estimated that about 10% of patients admitted to UK hospitals suffer from harmful adverse events, of which half were preventable. A cost analysis study conducted by Vincent et al. (2001) to evaluate the incidence and costs of PSIs in UK acute hospitals found that out of a total of 1,014 patients, 110 (10.8%) suffered 119 PSIs (11.7%). These PSIs resulted in an average additional 8.5 days at hospital with a direct cost of £290,268. They also found that half of these PSIs (48%, n=53) and extra bed days (46%, n=460) were judged preventable. They also noted that one-third of the patients affected (34%, n=37) in the incidents suffered moderate/greater disability or death. With extrapolation, it was estimated that preventable PSIs could cost the NHS in England and Wales around £1bn per year for additional bed days alone, resulting from patients' prolonged stay as a result of PSIs. A report released by the UK DH (2013) stated that in 2011/2012, half a million NHS patients (0.4%) experienced incidents of harm and 3,000 (0.003%) died owing to preventable PSIs.

1.3 Medication safety incidents

1.3.1 Definitions related to medication safety

In the academic literature, drug related problems are commonly defined as being *medication errors*, *adverse drug reactions*, or *adverse drug events*. This section aims to give currently accepted definitions each of these terms.

The definitions of *medication errors* in the academic literature are contrasting in nature, with early depictions suggesting that *medication errors* are, 'A *deviation from the physician's medication order as written on the patient's chart.'* (Allan and Barker, 1990).

More recently, medication errors have been defined by the National Coordinating Council for Medication Error Reporting and Prevention (NCCMERP) as:

'A*ny preventable event that may cause or lead to inappropriate medication use or patient harm, while the medication is under the control of the health care professional, patient or consumer. Such events are complex and may be related to professional practice – procedures and systems including prescribing, order communication, product labelling to areas such as packaging and nomenclature, compounding, dispensing distribution, administration, education monitoring and use*' (NCCMERP, 2017).

A widely cited definition has been proposed by Ferner and Aronson, who defined medication errors as, '*Failure in the treatment process that lead to, or has the potential to lead to harm to patients'* (Ferner and Aronson, 2006).

It is vital to consider that the *treatment process* in this definition, which is more commonly understood as the *medication use process*, is recognised as the process of prescribing, compounding, dispensing, drug administration and monitoring; all of which are initiated once the prescriber has made any decisions regarding patient treatment. An inability to carry out these processes through the attainment of identified standards is a failure on behalf of the practitioner. Therefore, a deeper understanding of the nature of medication errors indicate that they are both avoidable and preventable in the *treatment process* (Ferner, 2012).

The World Health Organisation's (WHO) interpretation of adverse drug reactions (ADRs) is defined as:

> *'Noxious and unintended, and which occurs at doses used in man for prophylaxis, diagnosis, therapy, or modification of physiologic function'*(WHO, 2002).

In contrast, the interpretation of adverse drug events (ADEs) has been understood as:

> *'An injury resulting from medical intervention related to drugs' (Bates et al., 1995)*

In literature related to drug related problems the terms ADRs and ADEs are sometimes used interchangeably (Murphy and Lee, 2015), through it has been suggested that ADRs include all incidents that include only appropriate usage of drugs (this excludes all incidents of poisoning, intentional overdose and therapeutic failures), whereas ADEs recognise both appropriate and inappropriate drug usage as being events of drug related mishaps (Nebeker et al., 2004).

Despite the contrasting definitions of ADRs and ADEs, this is leading to difficulties in interpreting the literature and direct comparison of studies. Thus, literature indicates that whilst ADRs are not preventable (Morimoto et al., 2004), the nature of both ADEs and medication errors display minor overlap.

Though medication errors, ADRs and ADEs are the most commonly understood forms of drug related problems, academic literature has additionally reported e*vents without harm*, in which an act of omission or commission may have occurred, but no actual harm, owing to fortuity, on the patient has transpired; and *near miss* is an act of commission or omission of potential that could have harmed the patient , but prevention of harm, as a result of strategic or coincidental recovery resulted (Kaplan and Fastman, 2003). The relationship between these kinds of drug related problems is shown in figure 1.3.

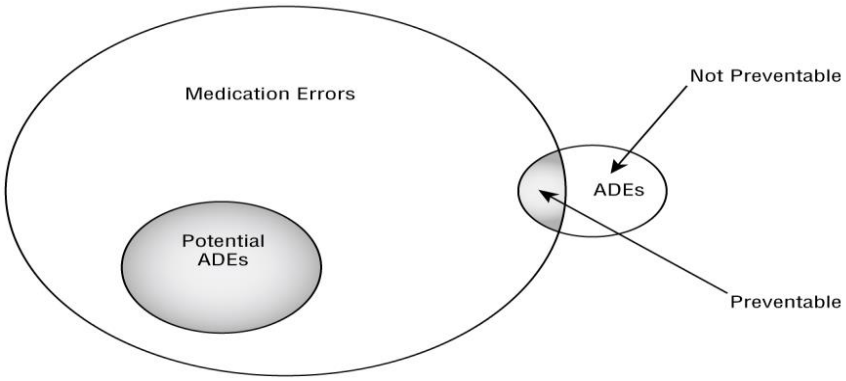


Figure 1.3. The relationship between medication errors, potential adverse drug events (ADEs), and ADEs. Adapted from (Kaushal et al., 2001a)

1.3.2 Medication use process

The medication use process is complex and involves the stages through which medications pass before reaching the patients as described in Figure 1.4. Within hospital settings, the stages include (1) prescribing e.g. by doctors or pharmacists; (2) transcribing; (3) preparing and dispensing; (4) preparing and administration, often by nurses; and (5) monitoring for both therapeutic effect and possible adverse events (Institute of Medicine et al. 2007). All of these stages are susceptible to error. In paper-based prescribing, these stages involve about twenty steps, forming a complicated system, giving rise to twenty opportunities for medication errors

to occur. The "five wrongs" are the classical types of medication errors: wrong medicine, wrong dose, wrong route, wrong time and wrong patient, which can occur at any prescribing, transcribing, dispensing and administration stages (Vogenberg and Benjamin, 2011).

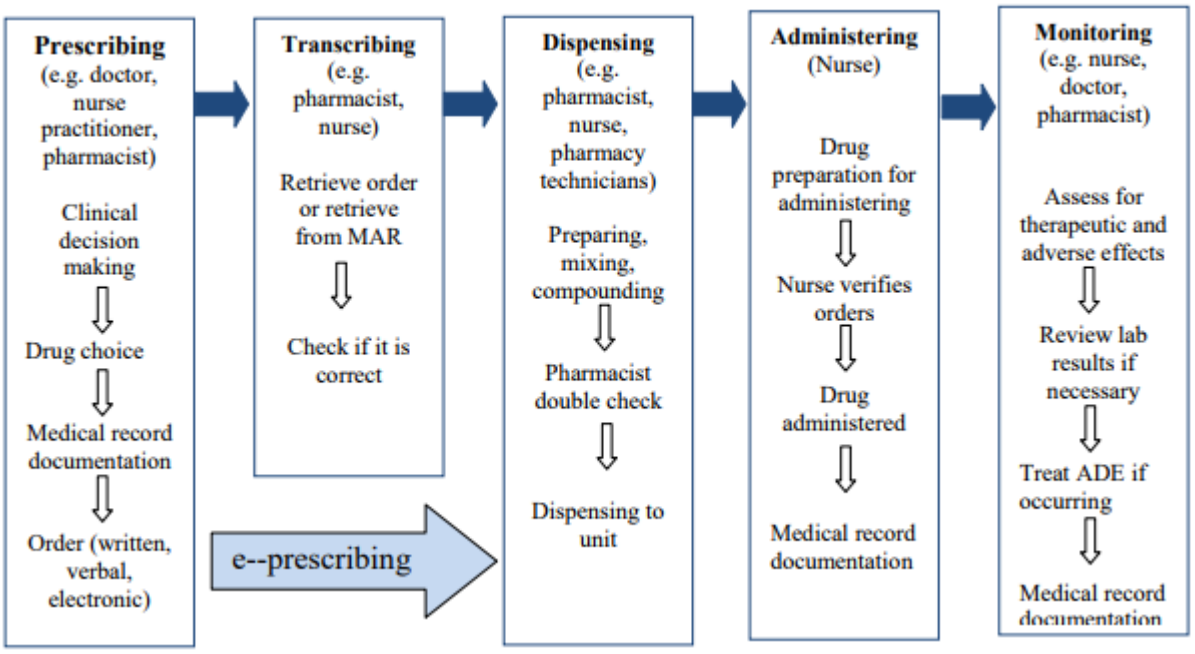


Figure 1.4. Medication use process in Hospitals (Institute of Medicine, 2007).

1.3.3 Human error theory

Human errors are linked to uncertainties associated with an inherent part of human performance (Reason, 1990, Reason, 2000). Being human is associated with inevitable human errors especially during routine prescription practices when external factors such as workload and pressure are considered, although these errors can be mitigated through adequate support which includes updated protocols and guidelines, clinical updates and training.

Early health service incident frameworks noted that most errors were largely human induced, without a focus on the systems and processes the human was working within. This approach is also known as blame culture, where an individual will be suggested to be the cause of error, absolving the institution from the responsibility for the error, and preventing any further investigation into system failures (Armitage, 2005, Armitage and Chapman, 2006, Wolf, 2007). However, when human error is involved, several other issues must also be considered and hence, (Reason, 1990) categorised three human error sub-types; skill based errors, rule

based errors and knowledge based errors. These categories of human induced errors can take various forms ranging from activities such as lack of attention to patients or staff, constant interruptions and lack of concentration, not following recommended protocols, taking shortcuts, over confidence and self-reliance thereby refusing to share ideas and goals (Reason, 1990). Errors from these acts are collectively described as 'active failures' (Reason, 2000).

Active failures are taken to be the causative factors of human errors and do not need to look further for the causes, since they have the person to blame. However, according to Reason (2000), active failures are also exacerbated by other issues known as 'latent conditions'. Latent conditions are situations which transiently lie unnoticed until they accumulate to a noticeable threshold which can combine with active failures to cause a major incident to occur. Latent conditions include design faults, poor management decisions, lack of training and staffing levels (Reason, 2000) referred to these as the 'Swiss Cheese' model of error; which implies certain anomalies / cracks in the system may pose no problems for several years, however as soon as the all conditions gets to a high threshold, they assemble to cause a 'trajectory of accident opportunity' (Figure 1.5). Therefore, it is imperative in any organisation that errors mimicking this pattern are identified and tackled accordingly.

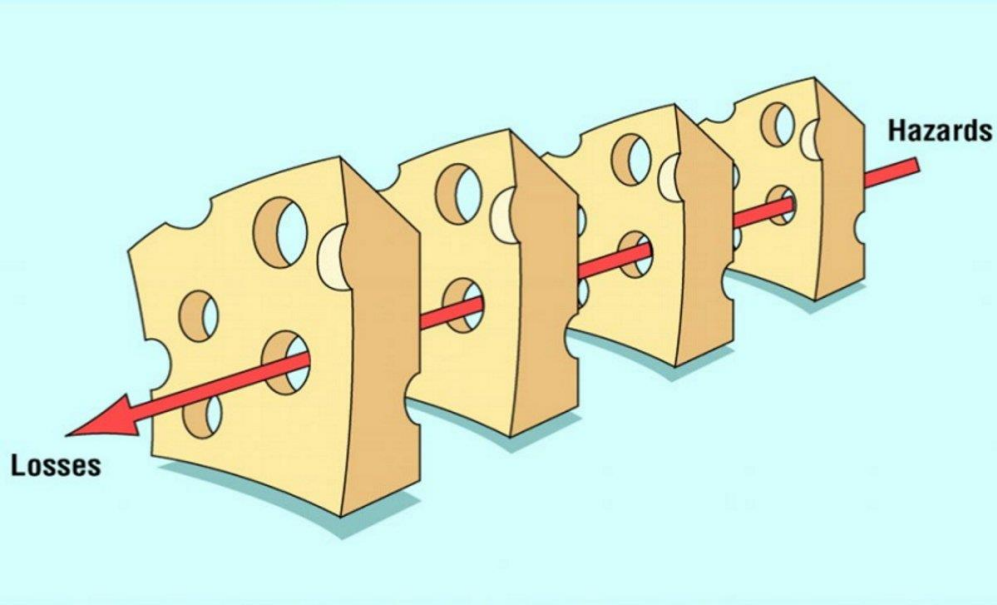


Figure 1.5. Reason's Swiss cheese model of accident causation (from Reason, 2000).

Reason (2000) recommended that health care institutions as 'high reliability organisations' must ensure that all human and non-human activities (such as computers) are routinely checked, updated, and robust as possible in order to minimise error. This requires constant

review of past and on-going processes which can be complemented using staff who are themselves involved in the entire processes as they are often the very people likely to identify active errors, impending errors or situations leading to potential errors in the future (Robinson, 2004). These steps are vital to ensure a safe working environment with reduced error incidents and (Dean et al., 2002a) applied Reason's human error theory in their research which examined a group of forty-four traditional prescribers whom they interviewed. Findings from their research indicated that not only did the respondents include many of the active and latent factors in their responses as categorised by Reason (1990), the prescribers themselves could also identify situations which led to the occurrence of the errors in the first instance.

Similarly, Marck and co-workers (2006) recruited practitioners in their study targeted at utilising restoration science (a process study, redesign, and strengthen medication safety practices within existing resources) to improve medication safety in Canada (Marck et al., 2006). Their research goal was in line with the processes used in the maintenance of the ecosystem which specifically involve efficiency, effectiveness and sustainability. Findings from this research showed that the practitioners were able to identify several areas which had been breached owing to error and inconsistencies, such as medication safety education and the safety of the ward environment. They argued that compliance with safety practices as well as improved medication safety knowledge among staff was important, and noted that staff are important collaborators in error research.

Prescribing error research, by its nature, examines complex processes which the perspective of human error theory can help address. The ability to identify current problems and predict potential problems requires a close examination of systems through field work research, with supplementary root cause analysis. This method was implemented by Knudsen and co-workers (2007) where they examined transcription errors. They identified that using this process can prevent recurrence of similar errors in future. Utilising staff bolsters a proactive, rather than a reactive, approach to future prescribing training and education needs. This is applicable to a variety of personnel, and can minimise errors associated with medication induced injury following prescription errors (Knudsen et al., 2007).

1.3.4 Classification of Medication Errors

Medication errors have been classified psychologically as either *mistakes* or *skill-based errors* (Ferner and Aronson, 2006, Reason, 1995). It has been suggested that mistakes take place when an error occurs in the planning of an action, which can be classified as either knowledge-based errors, which take place owing to the lack of knowledge regarding medical practice; or rule based errors, conducted either owing to the misapplication of an established procedure, or the application of an inadequate procedure. In contrast, skill-based errors take place when a skilled practitioner executes a correctly planned action, which are classified as slips (action based errors), which occur for example when a practitioner may accidentally write the wrong medication; or lapses (memory based error) (Figure 1.6). Literature indicates that a clear distinction must be made between unintentional medical errors and medical errors caused through a violation of, or disregard of, formal medical procedures, in an attempt to study medical errors reliably (McDowell et al., 2009, Reason, 1995).

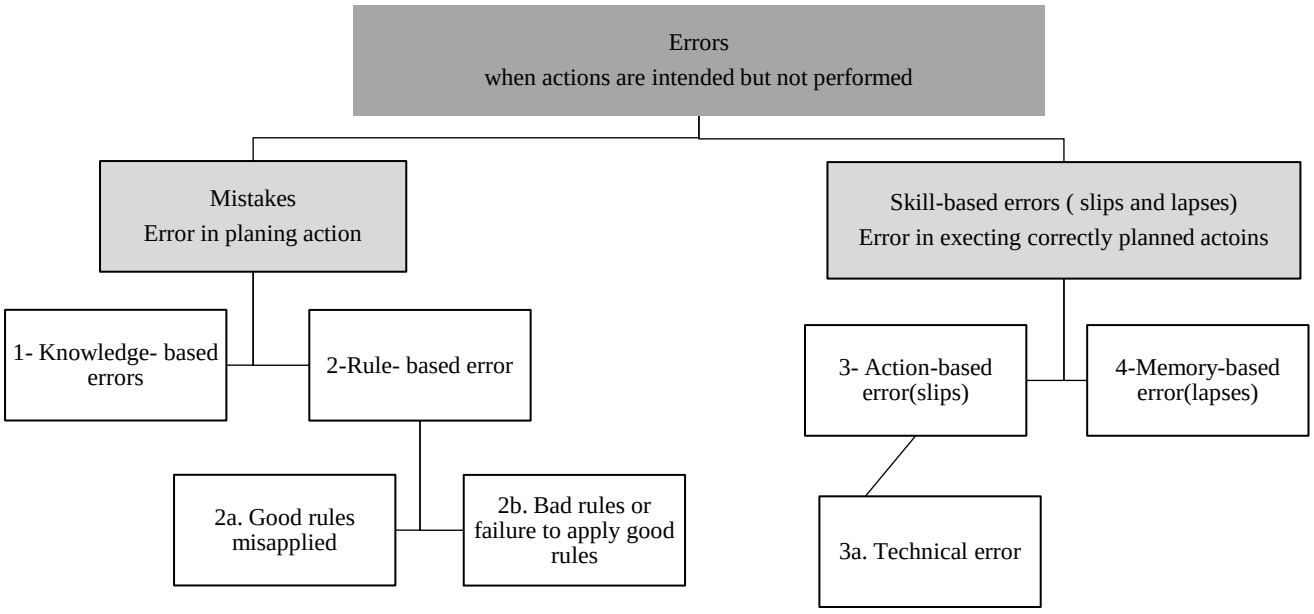


Figure 1.6. The classification of medication errors based on a psychological approach, (Ferner and Aronson, 2006).

Medication errors are also classified in accordance to which stage they occur in during the medication use process. This includes prescribing, transcription, dispensing, administration and monitoring of medications (Ferner and Aronson, 2006, ASHP, 1993, Van den Bemt and Egberts, 2007). Furthermore, a division can be made to categorise more specifically by the

nature of medication errors, which are classified as errors resulting from the wrong dose, wrong frequency, wrong route and wrong patient.

In addition, the severity of harm which is caused by a medication error is another classification in academic literature, which was adopted by National Coordinating Council for Medication Error Reporting and Prevention (NCCMERP). It classifies medication errors according to the severity of the outcome. In this system, medication errors are categorised from A to I (Figure 1.7), where for example a C category is a medication error that has taken place but has resulted in no harm to the patient, and a G category is where a medication error has occurred that may have contributed to or resulted in permanent patient harm (NCCMERP, 2001).

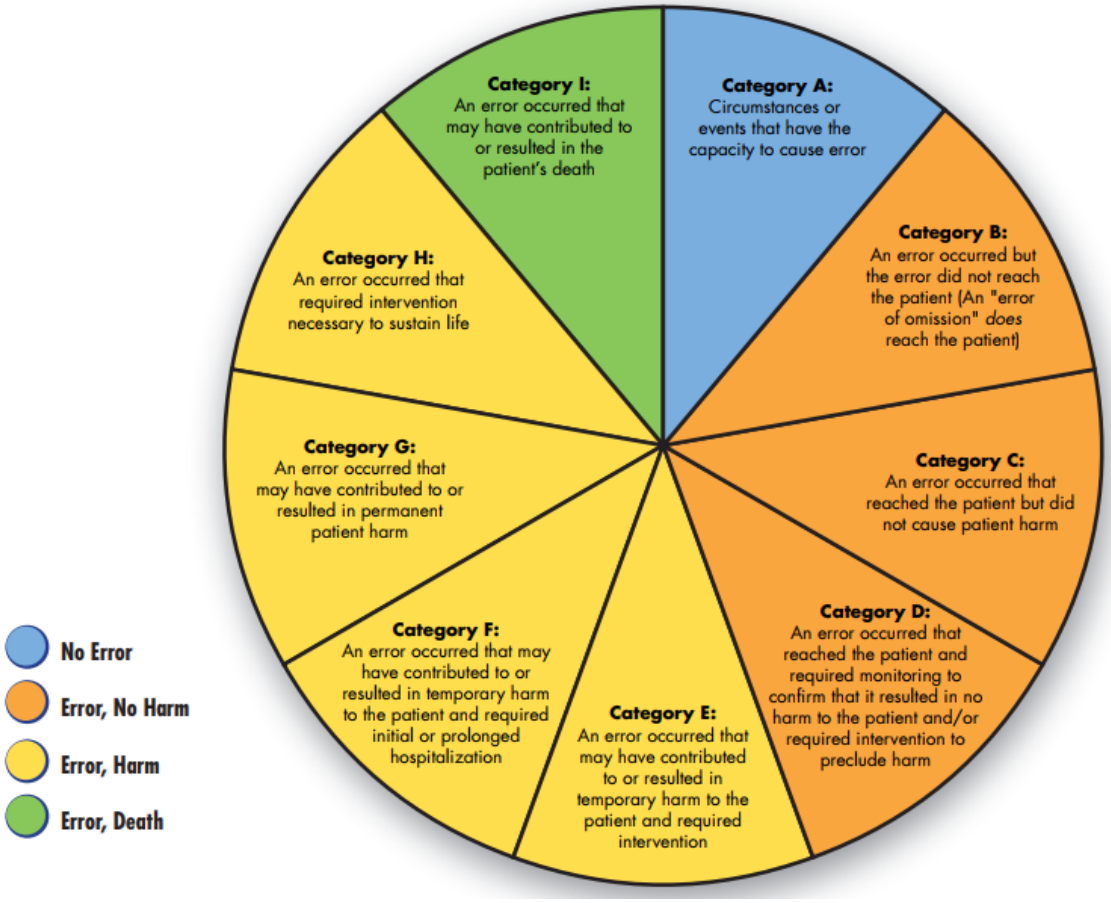


Figure 1.7. Categories of medication errors (NCC MERP, 2001).

1.3.5 Consequences of medication errors

Medication errors can have serious consequences on the health and safety of the patients with associated high financial cost incurred by most healthcare institutions (Bates et al., 1995, Bates et al., 1997, Hug et al., 2012, Kunac et al., 2009). It has being widely advocated by several

health institutions and regulatory bodies for health care practitioners to follow a strict code of practice as a measure required to mitigate against frequent medication error.

Several other researchers in the past have reported an average length of stay for a patient who suffers from complications resulting from preventable medication error. For example, Bates and co-workers reported that it takes about 4.6 days average additional length of stay (LOS) in a hospital to manage a patient who suffers preventable ADEs in a tertiary health care institution (Bates et al., 1997), while Hug and co-workers (2012) observed it takes about 3.15 days to manage such patients in a community setting.

Apart from the health and safety implications, medication errors also have serious financial consequences owing to the huge cost required to manage patients on a daily basis. Bates and co-workers (1997) reported that preventable ADEs costs over US$ 4685 in tertiary hospitals while Hug and co-workers (2012) reported a cost of US$ 3511 as the cost of preventable ADEs in community hospitals. The cost implications have also being reported based on the size of the hospital facilities. The estimated annual cost implications from preventable ADEs in a 700 bed teaching hospital stood at a staggering US$ 2.8 million (Bates et al., 1997).

Furtherance to the cost implications, the Adverse Drug Events Prevention Study Group at Harvard and researchers at Latter Day Saints hospital reported that ADEs prolonged patients' discharge from the hospital by 1.91-2.2 days on account of preventable medication errors and also reported an estimated additional cost of a single affected patients being hospitalised to be in the region of $2,013-2,595 (Bates et al., 1997, Classen et al., 1997). In agreement with the reports of Bates and co-workers (1997) and Johnson & Bootman (1995) in their research noted that morbidity and mortality rates associated with drug and medication errors cost the American healthcare system approximately $76.6-$136 billion annually (Johnson and Bootman, 1995).

It is important to note that these costs aforementioned do not include other costs required to manage psychological effects (e.g., pain, suffering, grief, and loss). Also, these costs do not include the money lost by governments and health institutions defending malpractice claim by patients, compensation to patients owing to injuries incurred during the process which account for greater percentage of any form of procedure-related health injury. Rothschild and colleagues (2002) noted that the average costs required to legally defend malpractice claims instituted by patients against health institutions caused by ADEs in the United states were

$376,500 for preventable inpatient ADEs and $64,700-74,200 for non-preventable inpatient and outpatient ADEs and preventable outpatient ADEs. These statistics sum up the enormous financial and resource implications resulting from medication error.

In the United Kingdom, the National Patient Safety Agency (NPSA) published a report in 2007 estimating that the NHS incurs about £774 million as the cost spent on the management of preventable medication incidents annually. The analysis of cost implications were based on the costs of avoidable hospital admissions (£359m), avoidable inpatient harms (£411m), and litigation costs (£4m) (National Patient Safety Agency, 2007). Primohamed and co-workers (2004) conducted similar research and reported that an avoidable 6.5% of hospital admissions are ADR-related, accounting for 4% of the occupied bed capacity in the hospitals. This costs the NHS £466 million annually (Pirmohamed et al., 2004). A study carried out by Cranshaw and co-workers (2009) showed that litigation costs from anaesthetic drug-related medication errors alone, between 1995 and 2007, cost NHS England Trusts £5 million.

1.4 Medication incidents according to the stage of occurrence in the medication-use process

1.4.1 Prescribing errors

One of the most commonly used definitions to describe prescribing errors, was developed by Dean and co-workers (2000) and is widely used in studies. The Dean and co-workers (2000) definition of prescribing errors is:

> *"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).

Dean and co-workers (2002) carried out a UK prospective study assessing the incidence and clinical significance of prescribing errors in a UK hospital. The study identified a 1.5% prescribing error among of 36,200 medication orders written over four weeks. While most of the errors occurred during the writing process (61%, n=328), 39% (n=210) of errors occurred during the prescribing decision process. A total of 26% (n=142) of the errors were potentially

fatal and 58% of the most serious errors occurred during the writing process. Dosing errors consisted 54% (n=289) of the total and errors that occurred when deciding the indication of a medication accounted for 18% (n=96), instructions of drug dispensing accounted for 13% (n=69), while drug administration errors accounted for 9% of errors (n=51).

A UK study (Ashcroft et al. 2015) carried out across 20 hospitals compared the junior doctor prescribing error rates to those made by other prescribers and senior doctors. 11,235 prescribing errors were identified in 10,986 orders of the 124, 260 medications checked, producing an 8.8% mean error rate for all prescribers. The rate of errors found for doctors in training were significantly higher than those of consultants. This was shown with error rates of 8.6%, 10.2% and 4.87% for foundation year 1, foundation year 2 and consultants respectively. The study identified the following as the most common errors: omission of required medications on admission (28.5%), under-dosage (10.9%) and over-dosage (8.4%) respectively.

In the US, Bates and co-workers (1995) pharmacists and nurses reviewed prescription charts in two US tertiary-care hospitals to assess the preventability and incidence of ADEs. Their results showed that 49% (n=128) of 264 preventable ADEs occurred during prescribing while 11% (n=29) occurred during transcribing stage (Bates et al., 1995). Winterstein et al. (2004), in a US study, analysed medication incident reports in a tertiary hospital and found that 72.5% (n=174/240) of medication incidents occurred during prescribing and 6.3% (n=15/240) of incidents occurred during transcribing stage.

Prescribing errors are common in paediatrics. Ghaleb et al. (2010) conducted a study across five London NHS hospitals and found that 13.2% (n=391/2955) of medication orders were associated with prescribing errors. Incomplete prescriptions (41.2%, n=161), use of abbreviations (24%, n=94) and dosing errors accounted for the most common types of prescribing error. Another prospective study on medication errors in paediatrics across two teaching hospitals revealed that the errors occurred mostly during the prescribing stage (74%, n=456/616), while only 10% of errors occurred in the transcribing stage (Kaushal et al., 2001b), with dosing errors accounting the highest proportion of errors (34%) of errors.

In a systematic review conducted by Lewis and co-workers (2009) the incidence, prevalence and nature of prescribing errors in adult or paediatric hospital settings was analysed. 65 studies (22 from the UK and 25 from the US) included in the review identified that errors were found in 7% of medication errors, which is equivalent 52 errors per 100 admissions and 24 errors per 1000 patient days. Dosing errors were identified as the most common error (Lewis et al., 2009).

These studies were conducted in a large number of patients and showed that that prescribing errors are common in both adult and paediatric populations, despite the rates of prescribing errors varying between the populations and study types.

1.4.2 Dispensing error

One of the core functions of professionals in a pharmacy is dispensing. Community and hospital pharmacies in England and Wales dispense about 900 million prescription items yearly as reported by the (National Patient Safety Agency, 2007). In England, over 1 billion prescription items were dispensed in 2013.

Dispensing errors have been defined as:

> *"A discrepancy between a prescription and the medicine that the pharmacy delivers to the patient or distributes to the ward on the basis of this prescription, including the dispensing of a medicine with inferior pharmaceutical or informational quality."*(Cheung et al., 2009).

A literature review of international studies was carried out by James and co-workers (2009) on the incidence and nature of dispensing errors. This review involved 18 studies each from the UK and US, reporting hospital pharmacy errors with the aim of identifying the rate of prevented (i.e., errors intercepted before they leave the pharmacy) and un-prevented dispensing errors (i.e., detected after the medicine left the units). The rate of prevented dispensing errors ranged 0.11% to 2.7% (8 studies) in the UK hospitals in comparison to the US hospitals with higher rates ranging from 0.06% to 18% (16 studies). The US hospitals reported un-prevented dispensing errors of 0.75% from just one study whereas the UK hospital reported errors ranging from 0.008% to 0.02% (n=9 studies). Dispensing the wrong medicine, dosage, quantity or strength were highlighted as the most common un-prevented error types. The most common automated and manual systems dispensing error types were labelling errors and the wrong medicine or strength dispensed (James et al., 2009).

1.4.3 Medication administration errors

Medication administration is the last stage of medication use process before medications reach a patient and has been a focus of research for a long time, especially the issues of errors during administration of medications in hospitals. The Nursing Interventions classification defined medical administrations as:

> *"Preparing, giving, and evaluating effectiveness of prescription and non-prescription medications"* (Gonzales, 2010).

In the UK, administration incidents ranged from 46.5% (Ashcroft and Cooke, 2006) to 83.3% (Maidment and Thorn, 2005) and were significantly higher than other stages of the medication use process. A retrospective analysis of medication incidents was carried out by Ashcroft and Cooke (2006) using data from an online reporting system at a large teaching hospital (1000 beds) over 26 months. Their findings showed that of the 495 incidents submitted, the administration, prescribing and dispensing stages each accounted for 46.5%, 38.8% and 14.7% of incidents respectively. A Scottish retrospective study analysing medication incidents reported to an online reporting system in Scottish primary care and acute and community hospitals inputted over a period of 46 months showed that the majority of reported incidents were administration incidents (Alrwisan et al., 2011).

1.4.4 Monitoring errors

The last stage of medication use process is considered to be medication monitoring, which is performed to promote efficacy and safety of medications administered. Monitoring errors have been defined as:

> *"A monitoring error occurs when a prescribed medicine is not monitored in the way which would be considered acceptable in routine general practice."*(Alldred et al., 2008).

While inappropriate monitoring of patients has been shown by studies to possibly cause harm, less attention has been paid to them in medication safety research when compared to other

medication use process stages particularly that occur in hospitals (Bates et al., 1995, Kopp et al., 2006, Lisby et al., 2005).

According to an NPSA report (2007), 3.8% (n=2424) of hospital reported medication incidents were monitoring accidents. In the US, Kuo et al. (2013) found that monitoring errors accounted for 14% (n=85/605) of inpatient medication incidents.

1.5 Review of Prescribing Errors

Prescribing errors as defined earlier (section 1.4.1) are the main target for the clinical pharmacy interventions (Cortejoso et al., 2016) and will be the key feature of this thesis.

According to the definition, there are two phases of prescribing (1) a decision-making phase (mental process) (2) writing phase (practical process). The decision-making phase influences the treatment procedure being adopted with the correct medication selection, whereas, the writing phase is process of writing the prescription to ensure the accuracy, clarity and legitimacy of prescription writing and is a technical stage.

1.5.1 Prescribing errors in secondary care settings

Prescribing errors are very common in secondary care settings comprising a major component of medication errors, and junior doctors are found to be more responsible for them (Ashcroft et al., 2015).

Dean et al. (2002b) carried out a study in a UK hospital to investigate the incidence and clinical significance of the errors arising during the drug prescription process. The study assessed 36,200 written medication orders over a period of four weeks. The overall error rate of all medication orders prescribed was 1.5% (n=538). The writing process was found to be responsible for (61%, n=328) of all of the prescribing errors. The prescription decision process was involved in 39% (n=210) of errors. The mechanisms for the errors were, wrong dosage (54%, n=289), uncertainty about the drug treatment to be given (18%, n=96), directions about drug provision (13%, n=69) and orders about the route of administration (9%, n=51). The writing process during prescribing accounting for (58%) of the serious errors detected.

A large study carried out across 20 hospitals in the UK examined the prevalence of prescribing errors arising during prescribing among different health care professionals including medical and non-medical prescribers (Ashcroft et al., 2015). Pharmacists assessed medication orders to establish prescribing errors associated with drug orders. In 10,986 orders 11,235 prescribing errors were found which was an all prescriber error rate of 8.8%. Consultants were less responsible for prescribing errors (4.87%) compared to trainee doctors (foundation year 1 (8.6%) and foundation year 2 (10.2%)). Omission of required medicine on admission was the most common type of error identified (28.5 %), followed by dosing errors (19.3 %).

Adverse drug events (ADEs) incidence and preventability were analysed in two US tertiary-care hospitals by Bates et al (1995) through the assessment of pharmacists and nurse charts and self-reports. Their assessment results showed that of the 264 preventable ADEs, 49 % (n=128) occurred at the stage of prescribing while the transcribing stage had a 11% (n=29) of preventable ADEs. In another study conducted by Winterstein and co-workers in one US tertiary care hospital to identify the types of medication errors. Results showed that 72.5% (n=174/240) of errors occurred at the stage of prescribing while 6.3% (n=15/240) occurred at the stage of transcribing (Winterstein et al., 2004).

Lewis et al. (2009), produced a systematic review to quantify the prevalence, incidence and nature of prescribing errors in hospitalised adult and paediatric patients. The review included 65 studies (25 from the US and 22 from the UK), and identified that prescribing errors occurred in 7% of medication orders, 52 errors per 100 admissions and 24 errors/1000 patient days. The review revealed that the dosing errors were the most common type of prescribing errors (Lewis et al., 2009).

These studies involving large numbers of patients show that prescribing errors are common in inpatient settings.

1.5.2 Prescribing error detection methods

The detection of prescribing errors is necessary to achieve any progress in patient safety by exploring updated prevention strategies to improve safe prescribing. The detection of these errors can be promoted through reporting of medication errors. There are several approaches

adopted in view of the difficulties encountered trying to ensure that clinicians voluntarily report errors. The following sections explain the 5 commonly used methods of error identification in documentation.

1.5.2.1 Incident reports

This method is the most commonly used perspective in a health-care system. There are two types of reporting: self-reporting from the clinicians or from other health care professionals who are aware of any errors and those generated by medication safety officers (Bates et al., 1995). This method is inexpensive and easily applicable. One of the biggest disadvantages of this reporting method resides in adverse events underreporting as it voluntary and relies on awareness , vigilance and honesty (Pham et al., 2013). It has a high level of bias.

1.5.2.2 Patient chart review

This method involves retrospective review of different patients' charts such as medical charts and laboratory data, prescription data, and discharge summaries (Montesi and Lechi, 2009, Morimoto et al., 2004). The quality of events identified by this technique rely on the accuracy of documentation and the reviewers' capabilities to capture the errors (Montesi and Lechi, 2009). This method has been found to be less accurate when it is used to quantify the error rate (Montesi and Lechi, 2009).

1.5.2.3 Direct observations

This method comprises the observation of the administration of medicines at the patient's own bedside to evaluate and identify any discrepancy between what the patient receives and the medical prescription. This method is the most reliable and effective used to detect and quantify the administration errors and is also a valuable approach for detecting dispensing errors (Montesi and Lechi, 2009). However, this method is time consuming and resource intensive (Stockwell and Kane-Gill, 2010).

1.5.2.4 Pharmacist interventions

Drug chart reviews are being used in many clinical areas by pharmacists (Montesi and Lechi, 2009). In the UK, pharmacists routinely add extra annotation to patient charts in order to amend or add additional medicinal information (Burgin et al., 2014). There may be clarification about the medication, its route of administration, and dosage between the prescribers and the pharmacist. In inpatient settings, these types of information are conducted either electronically or verbally and can be very fruitful, informative and render good guidance. Documented records of these interventions are often collected, either on papers or electronic systems, which can be of great help for junior doctors and pharmacists in a way that mistakes caused during prescribing may be identified and any flaws in the sequence of data may be identified and possibly rectified.

1.5.2.5 Adverse drug event trigger tools

Trigger tool utilise an efficient sampling technique to identify potential adverse events by auditing all medical records periodically (Resar et al., 2003). Each tool is made up of a limited number of triggers that signal the most frequent forms of adverse events or those with greater potential to cause harm to the patient. When a trigger is detected, the medication chart is reviewed to establish whether an adverse event has occurred (Resar et al., 2003). There are three types of triggers: using vitamin K as an antidote to treat over-anticoagulation effect of warfarin, or using flumazenil to treat over-sedation caused by benzodiazepines (Cavell, 2009); abnormal laboratory tests results which can be used as an indicator for an ADE; and clinical events that may indicate an ADE (Resar et al., 2003).

1.5.3 Causes of prescribing errors

Prescribing errors can be categorized into error producing conditions; work environment factors, team factors, individual factors, patient- specific factors and task factors (Dean et al., 2002a).

1.5.3.1 Work environment

1.5.3.1.1 Distractions

The atmosphere of the working place in which prescribing activities take place plays an important role in the outcomes of those activities. Chaotic and interruptive environments during prescribing have a negative impact on prescribers' focus. Clinicians have reported that interruptions during medication prescribing are the biggest cause of prescribing errors (Ryan et al., 2014). Empirical evidence indicates that distractions, combined with heavy workloads, contributed to over 60% of medication errors in anaesthesia care units (Hicks et al., 2004). In a study conducted in a wide range of clinical specialities, the distracting environment was found to be the main contributing factor for prescribing errors (Härkänen et al., 2015).

1.5.3.1.2 Workloads

High workloads are also likely to lead to errors and prescribing errors have been reported to increase with high workload (Dornan et al., 2009). Also, time of day and shift work have been found to contribute to the numbers of errors, as more prescriptions are written in day shifts compared to evening and night shifts (Lesar et al., 1990, Raju et al., 1989). Landrigan et al. (2004) also reported interns made more prescribing errors after working longer shifts than when they worked shorter shifts.

1.5.3.2 Staffing

Inadequate staffing is one of the causes of prescribing errors and studies have suggested an inverse relationship between understaffing and prescribing errors (Dornan et al., 2009, Hicks et al., 2004). It was reported that understaffing put clinicians under pressure leading to an increase in the prescribing errors (Ryan et al., 2014).

1.5.3.3 Team factors

Team factors include; inadequate supervision & responsibility, poor communication and low morale. Communication problems can lead to misinterpreted orders, oral or written, or inaccurate interaction with other services. A US report stated oral and written miscommunications in care settings were the major causal factors of prescribing errors (Moghaddasi et al., 2017). Examples of written miscommunications such as poor handwriting and transcription were the likely culprits in fatal overdoses associated with medication errors (Phillips et al., 2001). Also, Taxis and Barber (2003) reported that 16% of medications were omitted because of communication failures.

Inadequate supervision has not gained much attention as a cause of prescribing errors in the literature, however, a qualitative study discussed several examples with regard to prescription errors. Dean and co-workers (2002) presented examples in which junior doctors had inadequate supervision when prescribing medications. Senior doctors asked junior doctors to prescribe with their own initiative, which was identified to affect the risk of prescribing errors. Inexperienced junior doctors assumed responsibility would rest with the senior doctor in case of prescribing errors.

1.5.3.4 Personal factors

Insufficient knowledge and inadequate performance have been described as examples of personal factors that contribute to prescribing errors. Several studies showed that the lack of knowledge of certain drugs can lead to prescribing errors, accounting for 15-22% of errors (Dean et al., 2002a, Leape et al., 1995, Phillips et al., 2001). This combined with lack of knowledge about the appropriate drug therapy for a patient (e.g. misapplication of drug therapy) accounted for 60% of prescribing errors in a tertiary care teaching hospital (Lesar et al., 1997b). A lack of patient information (such as laboratory results) , has been reported to account for 24 % of prescription errors in two tertiary care hospitals (Leape et al., 1995).

Performance deficit has also been identified as a significant personal factor that contributes to prescribing errors. Performance deficit has been defined as the person delivering care lacking the requisite skills and knowledge to perform a particular task safely (Hicks et al., 2004). It

was reported that performance or knowledge deficits accounted for 65.2% of errors in hospitals (Phillips et al., 2001). Lesar et al. (1997a) identified that in hospital, more than 1 in 6 prescription errors included miscalculation of dosage, incorrect decimal point placement, wrong measurement unit expression or an incorrect medication administration rate.

1.5.3.5 Patient factors

Patient specific factors include age, the number of drugs they are taking, and comorbidities. Generally, elderly patients tend to be more prone to health risks, however, in the case of ADEs, evidence implies this is not the case. Lesar et al. (1997a) found older patients were at risk of having prescribing errors, but, another study found that age was not associated statistically with a higher risk of errors (Evans et al., 2005). These contrasting results were evident in another study, which comprised of a cohort analysis and a case control (Bates et al., 1999a). In the cohort study, Bates and co-workers found that old age was a significant factor in the increased risk of ADEs, but owing to insufficient predictive power, these results were deemed insignificant in the multivariate studies. This is due to the cases and controls included in the multivariate studies. They concluded that the age factor was a limited factor and the magnitude of its risk was smaller than suggested in previous literature.

Additionally, (Bates et al., 1999a) also identified a borderline association between the numbers of drugs received and the risk of developing an ADE. Evans et al. (2005) also established a link between the number of patient of comorbidities and increased risk of ADEs and the link was more prominent with severe ADEs. But, there was no more evidence found that could support Evans' findings. This could be due to the lack of literature covering this area, since none of the patient factors presented consistent results.

1.6 Strategies to reduce prescribing errors

Numerous solutions have been proposed in order to reduce the incidence of prescribing errors and the associated patient harm. Some of these include altering the medical and non-medical prescribers' training, standardisation of prescribing charts, and using electronic prescribing systems (Dornan et al., 2009).

1.6.1 Electronic prescribing

Several initiatives and strategies have been proposed to prevent prescribing errors, one of these initiatives is through the implementation of electronic prescribing systems. In the UK it was argued that the introduction of the electronic prescribing systems would reduce errors (Department of Health and Social Care, 2018). Electronic prescribing systems can improve medication safety in the medication use process, which includes prescribing, dispensing, administration and monitoring. This can be improved in various ways for example by improving the clarity of medication orders, legibility, appropriateness of medications, information availability, reduction in the requirement to enter information manually and through automatic scrutiny of likely drug therapy problems (Ammenwerth et al., 2008, Appari et al., 2011, Bates et al., 2001, Black et al., 2011, Cresswell et al., 2013, Huckvale et al., 2010, McKibbon et al., 2011). However, the consequences of such systems on the drug management process in clinical settings are inconsistent, with issues remaining unidentified, and unexpected novel prescribing errors being reported (Black et al., 2011, Coiera et al., 2006, Garg et al., 2005, Hemens et al., 2011).

Electronic prescribing has been defined in various forms depending on the context in which it is applied and hence there is no standard definition currently. However, a computerised provider (prescriber, or physician) order entry (CPOE) is a common way of referring to such systems, as well as computerised decision support systems (CDSS), both of which appear in the literature (Car, 2008). The electronic order entry refers to the *"use of computing devices to enter, modify, review and output or communicate orders relating to requesting laboratory tests, radiological images, prescriptions and other treatments"* (Dobrev et al., 2008). The National Health Services (NHS) Connecting for Health (NHS CFH), a leading health organisation scheme known for implementing electronic prescribing applications within secondary and tertiary care through its National Programme for Information Technology (NPfIT), developed a definition of electronic prescribing, encompassing the above mentioned dimensions:

> *"the utilisation of electronic systems to facilitate and enhance the communication of a prescription, aiding the choice, administration or supply of a medicine through decision support and providing a robust audit trail for the entire medicines use process"* (Cornford et al., 2009).

There are two types of electronic prescribing systems: first and second generation of electronic prescribing. The first generation electronic prescribing systems in which prescriptions were entered electronically and then were delivered to the patients in printed form by hand. The second generation systems involve the prescriber entering the prescriptions electronically to a assigned pharmacy (push model) or to a centred repository (pull model) (Motulsky et al., 2013).

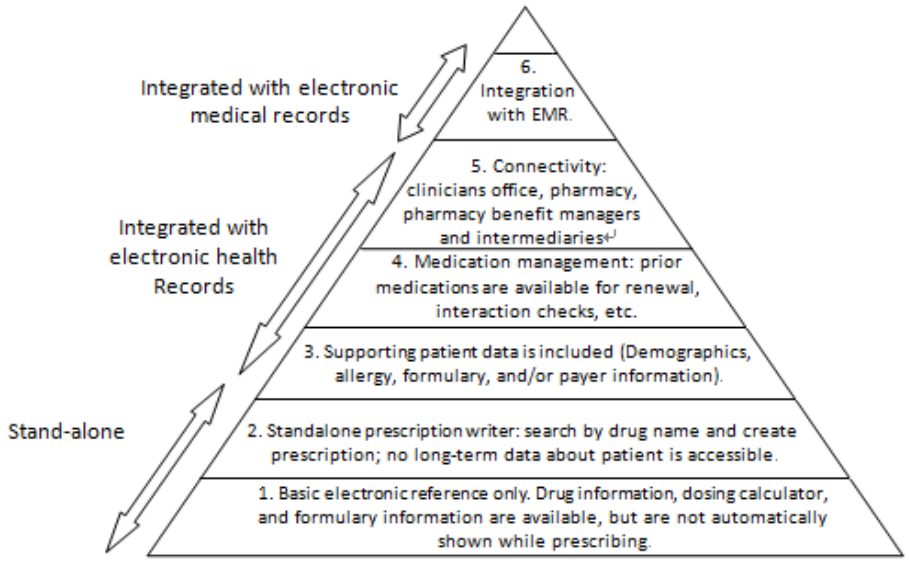


Figure 1.8. The level of sophistication of different electronic prescribing systems (Sheikh et al., 2011b).

There are different levels of sophistication of different electronic prescribing as shown in Figure 1.8. In this thesis the electronic prescribing system used related to second generation electronic prescribing model.

The adoption of electronic prescribing systems in the UK secondary care settings is modest when compared to primary care settings (Cresswell et al., 2014) which could be explained by different factors. The factors include, that electronic prescribing system is difficult to use and will be a new challenge for the users, the available systems are not developed sufficiently to deliver the expected benefit, or the perception that electronic prescribing system will cause major issue for work flow (Cornford et al., 2009).

1.6.2 Description of electronic prescribing systems

In an ideal situation, an electronic prescribing system would assist in generating the essential information required by prescribers to make an informed decision, for example, including patient data and evidence-based guidelines, which includes clinical decision support (Dixon and Zafar, 2009). However, most electronic prescribing systems also require other sub-applications to function such as:

- a repository of clinical data for patients, either as an electronic health record or electronic medication administration record: which includes patients' data and records where clinicians document history of all drugs administered to the patient (Bates, 2000).
- Knowledge-base: which includes the details of all items that can be ordered via the system, such as laboratory tests and medications that are from the local formulary. In an advanced system, the database also provides information on drug interactions, contraindications, dose ranges, possible allergic events and other related information. These features allow the electronic prescribing systems to perform as a safety net as prescriptions are entered (Black et al., 2011).
- Clinical messaging base systems: This helps to communicate the requested orders with other clinical information systems (Car et al., 2008).
- Computerised decision support systems (CDSS): These systems have different levels of sophistication to be incorporated into most electronic prescribing applications. Decision support is an application that provides real time support for ordering prescriptions regarding drug doses, routes and frequencies; perform checks for drug-allergies, drug–laboratory values or drug-drug interactions using computerised advice as well as providing reminders about the drug being ordered or treatment guidelines. CDSSs contain an inference mechanism known as the logic (a set of algorithms referred to as rules), applied to retrieve information from the knowledge-base and patient clinical data repository in order to generate clinical decision support recommendations, safety alerts and warnings (Kuperman et al., 2007).

Figure 1.9 illustrates the ramifications of electronic prescribing. Prescribing medication process is set of a complex actions occurring in a regulated process. The process involves a multitude of steps across locations and involves a diverse team, so it is not surprising that electronic prescribing systems are also organisationally complicated. The options available alongside their dimensions during implementation included in evaluation are also of a

multifactorial nature. Electronic prescribing system depicts the involvement of various healthcare professionals at different prescribing points.

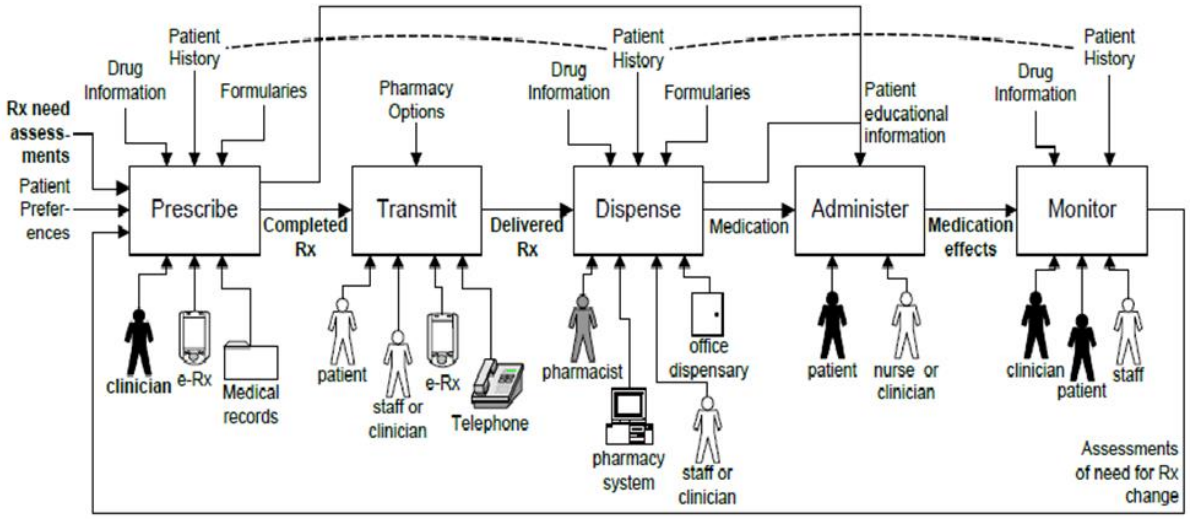


Figure 1.9. Architecture of electronic prescribing systems (Bell et al., 2004).

1.6.3 Impact of electronic prescribing systems on prescribing errors

The impact of electronic prescribing systems on prescribing errors has been demonstrated in previous research. The study by (Donyai et al., 2008) in a UK hospital showed that upon implementation of e-prescribing, a reduction in inpatient prescribing error frequency was observed. Prescribing errors were reviewed four weeks before and after the implementation of e-prescribing, which showed a 28 bed surgical ward had a reduction from 3% to 1.9 % in prescription interventions by clinical pharmacists, and a fall to 3.8% to 2% of prescription errors. Electronic discharge was not included as a component of the implemented system.

In the hospital reported in this thesis, Redwood et al. (2011) explored the type and nature of unintended of prescribing errors following the implementation of an electronic prescribing system. At the hospital site, where an e-prescribing system had been introduced incident reports related to medicines were analysed with an aim of detecting new types of errors called sociotechnical errors. These are errors that occur only because the system exists and has been implemented as they occur at points where the professional and the system intersect. Such socio-technical errors accounted for 15% (n=73) of reported incidents, of which almost half

were as a result of electronic signatures not recorded. However, medicine incidents were known to be underreported in this study being a significant limitation.

1.6.4 Application of electronic prescribing systems

The improvement in healthcare quality to ensure improvements that are longer lasting is the main aim of the independent UK charity, the Health Foundation, with its two main primary issues being patient safety and patient centred-care. In 2012, an evidence scan focussing on reducing prescribing errors was produced by the Health Foundation (The Health Foundation, 2012). Although electronic prescribing in hospital was highlighted as an important way of reducing prescribing errors, it also showed that a fall in performance may occur initially when this is implemented. The highest identified cause of error noted was when information regarding medication is not communicated completely across health care settings. They agreed that a fall in prescribing errors by 50% can be achieved by e-prescribing system implementation with decision support. The majority of the evidence scan studies reviewed were USA based, thereby creating a limitation to the application of the review to the UK systems.

Over the last decades, the medication management and medication prescription procedure have moved from paper based to electronic based systems (Odukoya and Chui, 2013). This change has yielded new challenges and tasks for clinicians and organisations. The introduction of such systems need to be conducted in accordance with clear standards, to ensure that new issues are not introduced and the best possible medicines management outcomes are achieved (Bonnabry et al., 2008).

In clinical settings, electronic prescribing can be assessed and evaluated through numerous approaches and techniques. Human interaction with the computer or the system and the setting in which an electronic prescribing system is to be used should be taken into account while evaluating the system (Cresswell et al., 2013). A comprehensive view with a socio-technical perspective should also be taken into account (Huckvale et al., 2010, Odukoya and Chui, 2013). A socio-technical approach implies that the implementation consequence has organizational, technological, and behavioural descriptions. There is a major gap between proposed and factually revealed outcomes of electronic prescribing technologies. Therefore electronic prescribing systems are not adequately evaluated, and where they are assessed, the results are

not often disseminated (Ammenwerth et al., 2004, Black et al., 2011, Cresswell et al., 2013, Garg et al., 2005).

One of the main applied research interests when studying how effectively an electronic prescribing system improves healthcare quality and safety is the scope for improvement of prescribing quality and prescribing errors reduction (Aspden et al., 2007, Baker, 2001, Erickson et al., 2003).

1.6.5 Benefits of using electronic prescribing systems in hospitals

1.6.5.1 Quality of care

Managing and storing patient data are two categories of electronic health applications being facilitated by electronic prescribing (Boonstra and Broekhuis, 2010, Li et al., 2013). The provision of such support is independent of the electronic prescribing functionality level and applications supporting decision capabilities that may inform and support decisions where possible (Samadbeik et al., 2013).

1.6.5.2 Patient safety

Though patient safety and the quality of healthcare are interconnected (Ash et al., 2007b), the basis of electronic prescribing systems use is specifically to reduce prescribing errors thereby medicines management safety (Barber et al., 2003). Research in the UK secondary health care settings shows that most serious errors in prescribing arise from a prescribing decision (Barber et al., 2003).

One of the areas that would benefit from using a CDSS is improvements in decision making (Black et al., 2011). Safety support and improved decisions are reliant on the configuration of alerts and how well decision support is integrated (Goldberg et al., 2013). Areas that would benefit from electronic prescribing systems include identification of patients, and improved communication between health providers (Black et al., 2011). To improve patient identification, the integration of electronic prescribing system and other clinical information systems such as electronic health care records and laboratory system is required (Cornford et al., 2009). This is all dependent on how integrated other clinical systems are.

An electronic prescribing system can be an effective intervention to reduce prescribing, thereby creating the potential to improve safety (Cornford et al., 2009). The system's level of sophistication, i.e. how well patient data is integrated with the system, the influence drug ontologies has on decision tools and how it is configured to individual prescriber's needs determine the reduction in the occurrence of various types of errors (Bell et al., 2004, eHealth Initiative, 2004).

Electronic prescribing can improve the quality control measures that allow prescribers' identification (prescriber name and prescription date) to be targeted at specific cases (Deetjen, 2016). Furthermore, it is possible to design a system to that can prevent orders that create risk from being processed (Bates et al., 2003), for example accidentally prescribing alendronic acid 70 mg once daily instead of weekly.

Moreover, from prescribing errors reporting and monitoring data, electronic prescribing systems can be used as a potential source of information to be used in quality and monitoring assurance in health care organisations (Coleman et al., 2011).

1.6.6 Government strategies

Secondary health care settings have had policies developed by NHS England that commit electronic prescribing systems as a future e-health model. An investment plan worth £260 million was produced by the Department of Health in 2013 aiming to make a paperless NHS England by 2020 (Department of Health, 2013).

A toolkit was produced in 2013 by NHS England for e-prescribing (NIHR Programme Grant for Applied Research 2013). The National Institute for Health Research (NIHR) funded research programme named "Investigating the implantation, adoption and effectiveness of e-prescribing systems in English hospitals: a mixed methods national evaluation" created the toolkit (NIHR, 2013). It is a multidisciplinary study involving a collaboration between Universities of Birmingham, Edinburgh and Nottingham. The English Department of Health funds NIHR with the aim of research being able to improve the nation's health and wealth. This e-prescribing toolkit is designed to offer NHS hospital prescribers information, resources and tools to aid planning, implementation and electronic prescribing use along each step.

1.7 Gaps in literature

Literature relating to evaluations of electronic prescribing systems implementation is insufficient. Solutions such as the implementation of systems are recommended by government strategies and policy documents to reduce prescribing errors and to improve medication safety, though there is little evidence supporting such claims.

There is a lack of publications addressing the implementation of electronic prescribing systems in secondary care settings and additionally there may be a positive publication bias as a result of unfavourable data being not published. This highlights that evaluative research that focuses on implementation of such systems is needed urgently, especially research related to the impact of electronic prescribing systems on prescribing errors.

1.8 Implications for the present research

Medications carry a risk of harm with research into medication-related incidents showing that a large proportion of hospital patient safety incidents are accounted for by these (Morimoto et al., 2011, Nuckols et al., 2007, Thomas et al., 2002, National Patient Safety Agency, 2007). Of the medication use process stages, the prescribing stage accounted for 18% of incidents reported (National Patient Safety Agency, 2007). Incidents at the prescribing stage are more likely to have an effect on subsequent medication use process stages as this is the initial stage. Furthermore, in the UK, medication incidents reports indicated that the prescribing error rates occur at 8.5% in secondary care settings, of them 2.1% having potential to cause moderate or severe harm (Elliott R, 2018), indicating that safety in medication prescribing has to be improved to reduce the occurrence of such incidents and the harm resulting from these incidents. To achieve this, these errors need to be understood.

1.9 Research Questions, Aims, Objectives

1.9.1 Research questions

The research questions which are addressed within this thesis are as follows:

- What is the state of evidence of the impact of electronic prescribing systems on the incidence of prescribing errors in hospital settings?
- What are the number, types, and severity of prescribing errors in an electronic prescribing system documented by hospital pharmacists within an electronic clinical intervention system?
- What is the role of hospital pharmacists in identifying and preventing prescribing errors?
- What are the causes and contributing factors of electronic prescribing errors in hospitals?
- What are the perceptions and attitudes of medical and non-medical prescribers towards the electronic prescribing system? And what are their suggestions on the system design issues to reduce prescribing errors.

1.9.2 Overall thesis aims

The aims of this thesis include:

- An evaluation of the literature examining the impact of electronic prescribing systems on the incidence of prescribing errors.
- An examination of the number, types, and severity of prescribing errors in an electronic prescribing system documented by hospital pharmacists within an electronic clinical intervention system, and their role in identifying and preventing prescribing errors.
- A qualitative evaluation of the causes, and associated factors, of electronic prescribing errors in secondary care.
- Evaluation of the perceptions of medical and non-medical prescribers towards the electronic prescribing system, including suggestions on system design to reduce prescribing errors.

1.9.3 Objectives

- To undertake a systematic literature review and meta-analysis designed to examine the impact of electronic prescribing systems on the incidence of prescribing errors in secondary care.
- To conduct a retrospective analysis of interventions reported by hospital pharmacists in the electronic prescribing system.
- To conduct a qualitative semi-structured interviews with a sample of medical and non-medical prescribers to identify the causes and contributing factors of electronic prescribing errors and their suggestions on the system design issues to reduce prescribing errors.

2 Chapter 2: The impact of Electronic Prescribing Systems on the incidence of prescribing errors within in-patients settings: a systematic review and meta-analysis.

2.1 Introduction

The Institute of Medicine (IOM) report *To Err is Human*, stated that 7,000 deaths in the United States annually were associated with medication errors (Kohn et al., 2000). Such errors can occur at any phase of the medication use process, namely prescribing, dispensing, administration and monitoring. However, several studies have shown that errors are most likely to arise during the prescribing stage (Bates et al., 1995, Bates et al., 1993, Bobb et al., 2004, Kaushal et al., 2001b, Winterstein et al., 2004). Consequently, these errors can lengthen the hospitalisation period (Bates et al., 1997) and double mortality rates (Classen et al., 1997). It has been estimated that preventable adverse drug events (PADEs) cost up to $5.6 million per hospital in the US (Bates et al., 1997) and £750 million annually in England (National Patient Safety Agency, 2007). Thus, improving patient safety and therapeutic outcomes are major challenges for health care providers and organisations.

In inpatient settings, prescribing errors occur between 1.5% and 15% in the UK (Dean et al., 2002b, Dornan et al., 2009, Franklin et al., 2011, Seden et al., 2013) and up to 6.2% of medication orders in the US (Bobb et al., 2004, Lesar et al., 1997b) . Variations of the reported error rates are influenced by different factors such as study methodology, definition of prescribing errors being applied and the denominator used for the reported error rate (Dornan et al., 2009).

As errors in prescribing are the main contributor to medication errors (Velo and Minuz, 2009), implementing electronic prescribing systems was one of the interventions proposed to reduce the risk of prescribing errors and improve medication safety (Bobb et al., 2004, Velo and Minuz, 2009). Computerisation is thought to have the advantages over hand-written prescriptions in terms of clarity, legibility, use of an approved drug name and completeness. There have been previous systematic literature search attempts to assess the impact of electronic prescribing systems in hospitalised patients (Ammenwerth et al., 2008, Chaudhry et

al., 2006, Eslami et al., 2008, Kaushal et al., 2003, Kuperman et al., 2007, Kuperman and Gibson, 2003, Murff, 2006, Nuckols et al., 2014, Oren et al., 2003, Shamliyan et al., 2008, Van Der Sijs et al., 2006, Wolfstadt et al., 2008, van Rosse et al., 2009, Garfield et al., 2018). None of these published reviews focused specifically on the incidence of prescribing errors. They included all types of medication errors and adverse drug events or focused on paediatric patients (van Rosse et al., 2009). Only one systematic review focused on the impact of computerised prescribing on the reduction of prescribing errors (Reckmann et al., 2009). However, this study has a narrow focus and does not draw a clear conclusion on the effectiveness of computerised prescribing on the incidence of error and fails to quantify the error rates associated with the use of such systems.

Therefore, the aims of this systematic review were to review the evidence of the effectiveness of using electronic prescribing systems to reduce prescribing errors in inpatient settings. A meta-analysis was also conducted, the objective of which was to determine the impact of electronic prescribing implementation on the incidence of prescribing errors.

2.2 Methods

2.2.1 Search strategy

The following electronic databases were searched systematically by principal researcher (FA): MEDLINE, EMBASE, Cumulative Index to Nursing and Allied Health Literature (CINHAL), ASSIA, PsycINFO, Cochrane Library, HMIC, and Web of Science (up to April 2016). These databases were chosen as they are very comprehensive and relevant to pharmacy practice research in order to maximise the likelihood of capturing all relevant research outputs and minimizing the effects of reporting biases.

2.2.2 Search Terms

The search terms used fell broadly into three groups: prescribing error [including error(s),prescribing error(s), medication error(s), prescription error(s), medication mistake(s), drug mistake(s), prescribing mistake(s), wrong medication(s), wrong drug(s), near miss(es), preventable adverse drug event(s), incident report(s)], electronic prescribing [including computerised prescribing, electronic prescribing, computerized ordering, electronic ordering] and hospital setting [including inpatient(s), hospital(s) and hospitalisation]. These keywords

were searched using MeSH headings and combined using Boolean operators (the full search strategy can be found in the appendix 1). The reference sections of eligible studies and relevant review articles were also hand searched to identify additional relevant studies. Relevant reviews identified from the electronic databases were also searched for additional potential studies.

2.2.3 Inclusion and exclusion criteria

The inclusion and exclusion criteria were developed based on the formulated research question of the systematic review and PICOS method (participants, interventions, comparisons, outcomes and study design).

Studies were only eligible for inclusion if the study met all the following inclusion criteria: (1) prescribing error was the outcome measure; (2) the reported data arose from a study conducted in inpatient hospital settings; (3) and if the study evaluated pre and post implementation of e-prescribing system or comparative investigations (handwritten vs e-prescribing). All quantitative study designs and prescribing errors definitions were included. Also, included were electronic prescribing systems regardless the level of decision support that they provided (e.g., with or without alerts on drug-drug interaction), and for all types of drugs. Also, studies of prescribing errors for all age groups were included.

Studies detecting prescribing errors on paper-based systems only, those conducted exclusively in primary care, emergency department, ambulatory care or aged care settings were excluded. Non-English literature as well as editorial, qualitative studies, personal opinion and letters were also excluded. Conference abstracts that did not provide sufficient information about the rate of prescribing errors were excluded.

2.2.4 Study selection

Titles and abstracts were screened by two reviewers for eligibility (Researcher and Senior Lecturer in Clinical Pharmacy). Full-text articles of potentially relevant studies were examined for eligibility. Disagreements about the eligibility were resolved by discussion and consensus, with a third investigator (Professor of Clinical Pharmacy).

2.2.5 Data extraction and Quality assessment

A data-extraction form was created to extract the following data from included studies: year and country, hospital and ward setting, study design, length of study, type of electronic prescribing system, number of patients and prescriptions, rate of prescribing errors including denominator used, and any other relevant outcomes. Authors of papers containing insufficient data were contacted for additional information.

An electronic prescribing system utilised in the included studies was classified based on its functionality basis as:

- Basic: selection of drugs from an electronic reference formulary with available doses, no further decision-support;
- Moderate: evidence-based patient-specific recommendation of a drug, dosing, frequency or give warnings for duplication
- Advanced electronic prescribing systems: at least some drug-allergy, drug-drug interaction, drug-lab, or other patient-specific alerts and advanced decision support capabilities.

Quality assessment is an important part of the systematic review process, rarely carried out in non-systematic narrative literature reviews. Quality of included studies was assessed using a 10-question assessment tool created by integrating questions from Randolph quality assessment tool which evaluates the quality of the literature using computer-based systems on patient outcomes (Randolph et al., 1999) and the Critical Appraisal Skills Programme (CASP) (Critical Appraisal Skills Programme (CASP), 2014). These quality assessment tools are used for quantitative studies. These tools were particularly chosen for their versatile ability to analyse randomized and nonrandomized studies, and have been deemed appropriate for systematic review (Car et al., 2008). The created tool (Appendix 2) was used to appraise the papers reviewed to identify potential source of publication bias. Also, the tool assessed the unit of randomisation, baseline difference characteristics, validity of the study, results and outcome measures clearly defined and the applicability of electronic prescribing systems. Each question scored two points which sums the scores between 0-20.

2.2.6 Data synthesis and analysis

Included studies were analysed with a focus on prescribing error rates, medication(s) associated with prescribing errors and any types of prescribing errors associated with using electronic prescribing systems. In addition, median error rates with interquartile ranges (IQRs) were calculated across studies. Some studies reported the prescribing errors rate only, whilst others reported all types of medication errors, which comprised errors in the dispensing and administration processes as well as prescribing errors. Studies were only included if the rate of prescribing errors could be determined specifically. For some studies, reported rates were converted to a common denominator to facilitate comparison across studies. For reported studies, the rate of errors in medication order(s) were converted into a percentage of erroneous orders. Studies showing rates per admission(s) were converted to rates per 100 admissions. Also, those studies illustrating an incidence of errors per patient day(s) were converted into errors per 1000 patient days.

Data were also sub-analysed to examine the error rate in adults and paediatric settings as well as the types of medication(s) involved in prescribing errors.

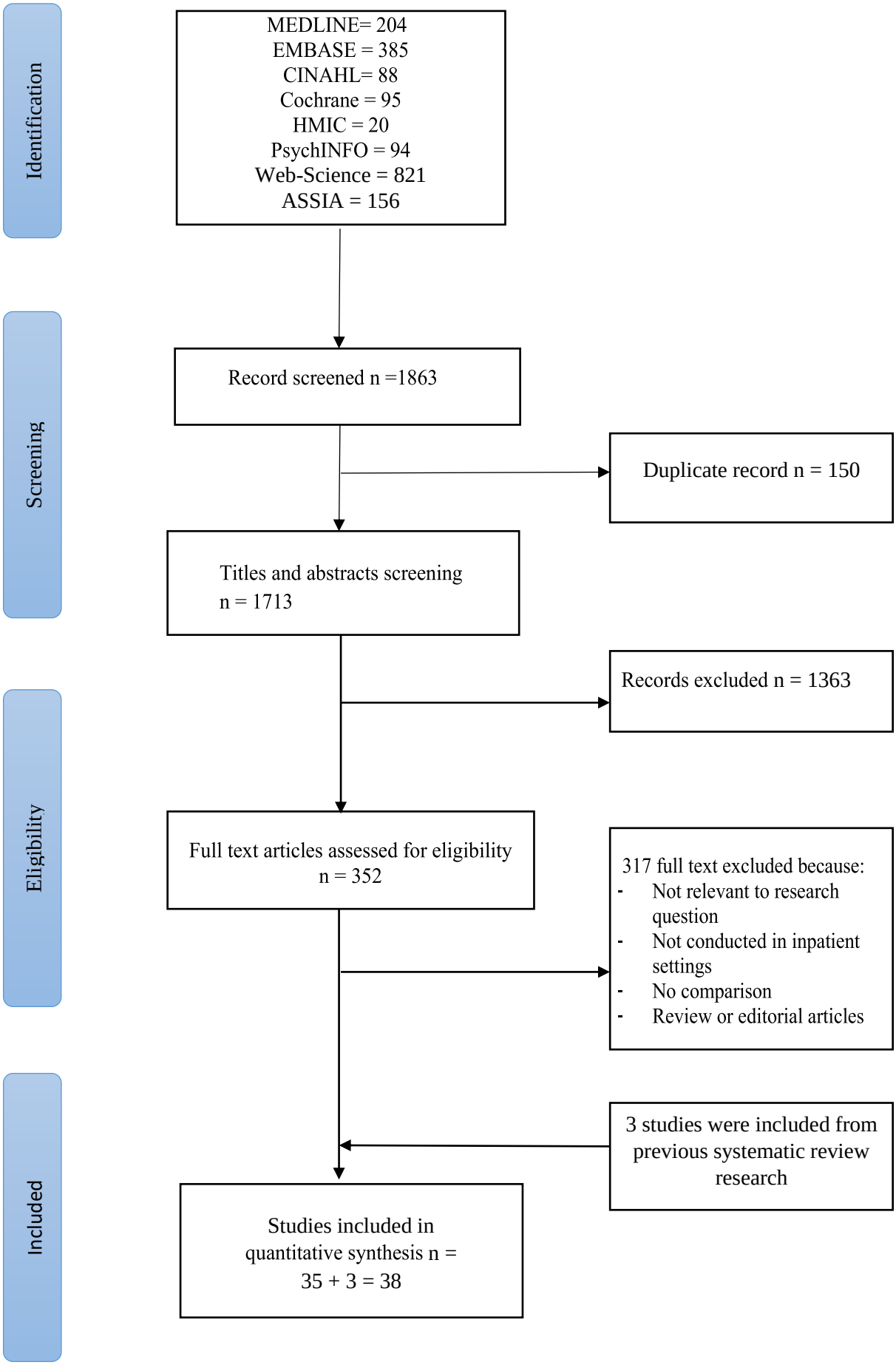
Finally, meta-analysis was conducted for prescribing errors for all eligible studies that had sufficient data to allow pooling using Mantel Haenszel random–effects model (Koper et al., 2013). Studies were eligible for inclusion if their scores achieved 50% or more using the quality assessment tool (see the appendix 3). For each eligible study, an odds ratio (OR) was calculated as the number of prescribing errors per unit of exposure in the electronic prescribing group divided by prescribing errors per unit of exposure in the paper-order entry group. Sub-group analysis was performed using graphical approach based on Forest plots. Subgroups were *a priori* defined as potentially relevant such as functionality (basic/moderate level, or advanced decision support), type of system (commercial or home-grown system), and patient age group.

Pooled odds ratio (ORs) and 95% confidence intervals (CIs) were calculated with random effect. Within meta-analysis heterogeneity was assessed using I^2 statistics. I^2 describe the variation across studies and ranges between 0- 100%. A P-value of 0.05 or less was considered significant.

2.3 Results

The result of the present search yielded 1713 outputs (Figure 2.1). A total of 1361 articles were excluded at the title and abstract assessment stage, as they did not meet the inclusion criteria. This left 352 articles for full-text evaluation. Of these, 317 were excluded as they were not relevant to the research question, not conducted in an inpatient setting, contained no comparison being assessed or addressed outcomes other than prescribing errors (for example, workflow or cost). Thirty-five were relevant. Three additional studies were identified using hand-searching of reference lists of included studies. Thirty-eight studies met inclusion criteria and were therefore included in this systematic review.

Figure 2.1. PRISMA Flow diagram of the conducted searches



2.3.2 Characteristics of studies

The characteristics of the 38 studies which were included are summarised in Table 1. Studies were most commonly conducted in the USA (13/38) or UK (9/38). Other countries included; Australia (n=2), Belgium (n=1), Canada (n=1), France (n=1), Iran (n=1), Israel (n=2), Pakistan (n=1), Singapore (n=1), Spain (n=4), The Netherlands (n=1) and Switzerland (n=1). The vast majority of included studies were published after 2000 (35/38).

Most of studies (28/38) were conducted in university-affiliated hospitals. Three studies (3/38, 8%) took place in general hospitals, two (5%) were carried out in a private hospital and one study did not state the type of hospital (Warrick et al., 2011). Four studies (10%) were conducted in paediatric hospitals. The majority of studies (32/38) had been carried out in single hospital sites and six on two sites (Barber, 2006, Choo et al., 2014, Mahoney et al., 2007, Redley and Botti, 2013, van Doormaal et al., 2009a, Westbrook et al., 2012).

Twenty-two studies (57%) took place exclusively in adult specialities or wards, twelve studies (31%) included only paediatric specialities or research from paediatric hospitals, with one study conducted in a neonatal intensive care unit (Cordero et al., 2004) and four studies (11%) included prescriptions for both adults and children. Only 5 studies (13%) were carried out in entire hospital (Jani et al., 2010, Mahoney et al., 2007, Menendez et al., 2012, Redley and Botti, 2013, Shawahna et al., 2011). The data collection period ranged from 5 days (Shawahna et al., 2011) to six years (King et al., 2003, Menendez et al., 2012). Data were commonly collected by pharmacists (21/38, 55%) or nurses (3/38, 8%). The overall study quality was poor with studies scoring on average 13 out of 20 on the rating scale (see appendix 3).

Table 2.1. Summary table of included studies

Source/ Country	Setting	Study design/length of study	Intervention	Number of patients and prescription (n)	Adult/Paediatric	Outcomes and findings
Ali et al. (2010) (UK)	1 teaching hospital 25 bed adult cardiothoracic ICU	Prospective, time series, cross-sectional study, consecutive sample. 7 months before; 5 and 12 months following implementation of CPOE	CPOE	Pre: 190 (4463) Post 5 months: 210 (5083) Post 12 months: 204 (5175)	Adult	Dosing errors reduced from 6.2% (229/3720 orders) to 0% (0/4828 and 0/4905orders) at 5 or 12 months post-intervention. No P value reported. Computerised prescribing system has improved prescribing error.
Armada et al. (2014) (spain)	1 tertiary care university centre. 9 bed cardiac ICU.	Prospective, longitudinal, before-after study. Phase1: 3 months pre implementation Phase 2: 1 month post implementation Phase 3: 3 months post implementation each phase lasted 21 consecutive days	CPOE+CDSS	Phase1: 43 patients (158) Phase 2: 44 patients (142) Phase 3: 50 patients (170)	Adult	Prescribing errors decreased from 44.8% (819 errors among 1829 prescriptions) pre-intervention to 0.8% (16 among 2094 prescriptions) at the final electronic stage ($P < .001$).
Barber et al.(2006) (UK)	2 hospitals. 28-bed general surgery ward (Hospital A) 4 wards in Hospital B (paediatric, general medicine, general surgery and medicine for the elderly).	Prospective before and after design for (ServeRx) system (Hospital A). Retrospective before and after design for (Meditech) system (Hospital B). 3-6 months before, and 6-12 months after the implementation.	2 different electronic prescribing systems	188 patients (2319 orders) pre and 201 patients (2319) post for (ServeRx) intervention. 25 patients chosen randomly from each ward before and after intervention of Meditech. (836) orders pre (880) orders post implementation.	Both	At Hospital A, prescribing errors reduced from 3.8% of medication orders pre-ServeRx, to 2.0% post-ServeRx $p = 0.0004$. At Hospital B, prescribing error rates were 8.6% and 8.8% pre- and post Meditech, respectively. Meditech did not have an impact on the incidence of prescribing errors.
Bates et al (1998) (USA)	1 tertiary care teaching hospital 2 intensive care units (ICUs) (1 surgical and 1 medical) and 4 general care units (2 medical and 2 surgical).	Retrospective Pre/post analysis 6-month before intervention 9-month after intervention	CPOE	Phase1: 2491 patients phase 2: 2047 patients	Adult	The rate of prescribing errors decreased 19% from 4.1 to 2.6 per 1000 patient days ($p= 0.03$).
Bates et al. (1999) (USA)	1 tertiary care academic hospital 3 medical units (One intensive and two general medical care).	Prospective time series analysis 4.5 years carried out over 4 separate time periods.	CPOE with CDSS	Baseline=10,070 prescriptions period 1=15,025 prescriptions period 2=13,139 prescriptions period 3=14,352 prescriptions	Adults	At final period of the study, dosing errors decreased 55.16% $p =0.03$, frequency errors decreased 91.67% $p < 0.0001$ and route errors decreased 85.71% $p < 0.0001$.

Source/ Country	Setting	Study design/length of study	Intervention	Number of patients and prescription (n)	Adult/Paediatric	Outcomes and findings
Choo et al. (2014) (Singapore)	2 tertiary care public teaching hospitals Hospital A (Control Site) 708 bed Hospital B (Intervention Site) 928 bed	Retrospective design with a control group. 12 month before implementation 12 month after implantation of inpatient electronic medication record system	Electronic medication record system	Not stated	Adults	Total number of prescribing errors was found 4 fold in hospital B (intervention site) more than Hospital A (control site) (41 vs 11). No p value reported. Overall implementation electronic medication record system did not affect the incidence of prescribing errors.
Collins and Elsaid (2011) (USA)	1 multidisciplinary tertiary care institution 719 bed	Retrospective before-and-after cohort study 24-month before 6 months after	CPOE	412 orders pre-intervention 126 orders post-intervention	Both	The rate of error reduced from 9.5 to 3.2 per 100 orders. A 69% reduction in total prescribing errors associated with electronic prescribing ($P = 0.023$).
Colpaert et al.(2006) (Belgium)	1 tertiary care university hospital 22-bed intensive care unit comprising 14 beds use traditional paper based prescription and 8 beds computerized prescription system	Prospective Controlled cross sectional trial 5 weeks	Intensive care information system with incorporated CPOE and a moderate level of CDSS	Total of 2,510 prescriptions comprising 1,286 electronic prescriptions and 1,224 conventional paper based prescriptions.	Adults	Prescribing errors were significantly lower with electronic prescribing compared with paper based system 3.4% versus 27% $P < 0.001$.
Cordero et al. (2004) (USA)	University Medical Centre Neonatal intensive care units	Retrospective cohort study pre and post CPOE 6 months before and 6 months after implantation of CPOE	CPOE	105 orders pre and 89 orders post of gentamycin being prescribed	Paediatric	Dosing errors reduced to zero after implantation of electronic prescribing system compared to 14 (13%) before implantation.
Delgado et al. (2007) (Spain)	General hospital with two clinical unit pneumology department (27 beds) infectious diseases department (26 beds)	Prospective two phases pre and post implementing the electronic prescribing system. Each phase lasted one month.	Electronic prescribing system	Total number of prescriptions in manual phase (839). Total number of prescriptions in electronic phase (610).	Adults	The rate of errors of treatment orders reduced from 14.4% to 1.3% following using electronic prescribing system ($p < 0.05$).
Donyai et al.(2007) (UK)	1 teaching hospital General surgery ward (28 bed)	Retrospective before and after design 4 week periods 3 months pre implementation 6 months post implementation	Electronic prescribing system	2450 medication orders pre-EP and 2353 orders post-EP.	Adults	Prescribing errors decreased from 94 (3.8%) to 48(2.0%) implanting electronic prescribing system. The absolute reduction of 1.8% was statistically significant (95% CI 0.9, 2.7%).
Evans et al., (1998) (UK)	1 ICU ward at a university hospital	Prospective before and after design 6 weeks duration 3 weeks before intervention. 3 weeks after intervention.	Electronic prescribing system	128 handwritten prescriptions 110 electronic prescriptions	Adults	Prescribing errors (for intra-venous fluids, intra-venous infusions and intermittent medications orders) increased from 12.5% (148/1184) pre-intervention to 24.4% (299/1225) post-intervention: No P value reported.

Source/ Country	Setting	Study design/length of study	Intervention	Number of patients and prescription (n)	Adult/Paediatric	Outcomes and findings
Fontan et al., (2003) (France)	1 Paediatric Hospital paediatric nephrology ward 12 rooms included	Prospective randomly comparing computerized and hand written prescription 8 weeks	Computerized prescription	49 patients with 511 prescriptions	Paediatrics	Electronic prescribing system showed a significant decrease of the prescription rate (from 87.9% to 10.6% with $P < 0.0001$).
Franklin et al.(2007) (UK)	1 teaching hospital General surgery ward (28 bed)	Prospective before-and-after design 4-week period 3–6 months before and 6–12 months after the intervention	Closed-loop electronic prescribing and administration system	Pre intervention 129 patients (2450 orders) post intervention 147 patients (2353 orders)	Adults	Prescribing errors rates fell from 3.8 to 2.0% of medication orders with relative reduction 47%, ($p < 0.001$).
Holdsworth et al. (2007) (USA)	1 hospital probably public PICU 20 bed general paediatric unit 30 bed	Prospective cohort study 6 months before and 6 months after implantation of CPOE	CPOE	1197 admissions before the introduction CPOE 1210 admissions after	Paediatrics	Electronic prescribing systems was associated a reduction of prescribing errors. However, dosing errors were persisting after implementing electronic prescribing system.
Jani et al. (2010) (UK)	1 paediatric hospital probably public 314 bed Entire hospital	Retrospective quasi-experimental, before–after study. 13-month period	CPOE with CDS	463 patients before intervention 500 patients after intervention	Paediatric	Following implantation of electronic prescribing, the total number of prescribing errors reduced 33(3%) to 19(1%) $p < 0.001$. However, no apparent change in error rates in inpatient 18 (1.42%) before compared to 29 (1.39%) after.
Jozefczyk et al. (2013) (USA)	1 tertiary care teaching hospital Neonatal intensive care unit 44-bed.	Retrospective review of medication orders before and after intervention	CPOE	1000 orders 500 orders pre intervention 500 orders post intervention	Paediatrics	The number of orders with zero opportunity of error increased from 42% (n = 209) to 98% (n = 480; $P < .0001$), in the pre- and post-groups, respectively.
Kadmon et al. (2009) (Irasel)	1 tertiary children's hospital PICU 12-bed	Retrospective cohort study 3 years.	CPOE + CDSS implementation in four different periods	5000 orders over 4 periods each period consists of 1250 consecutive prescriptions.	Paediatrics	Prescription error rates reduced significantly at period 4 compared to pre-implantation period 1 (18/1250) 1.4% vs (103/1250) 8.2% $P < 0.0001$.
Kazemi et al. (2011) (Iran)	1 tertiary care referral teaching hospital. Neonatal ward 17-bed with 2 NICU beds.	Prospective pre-post intervention study 7.5 months over three consecutive periods each period 2.5-month	CPOE + dose range alerts, frequency alerts, and renal function adjustment alerts.	total number: 248 patients Period 1:96 patients (1248 orders) Period 2:83 patients (1080 orders) Period 3:79 patients (878 orders)	Paediatrics	Prescribing errors rate reduced from 52% before intervention (period 1) to 34% after the decision support was added to the electronic prescribing system (Period 3; $P < 0.001$).

Source/ Country	Setting	Study design/length of study	Intervention	Number of patients and prescription (n)	Adult/Paediatric	Outcomes and findings
Kim et al. (2006) (USA)	1 academic medical centre. Paediatric oncology ward	Prospective pre-post intervention study 241 days before intervention 296 days after intervention	CPOE	176 patients before intervention (1259 orders) 167 patients after intervention (1116 orders)	Paediatrics	A significant reduction in error rates of chemotherapy ordering process were found after electronic prescribing introduced.
King et al., (2003) (Canada)	1 tertiary care paediatric teaching hospital 3 medical and 2 surgical wards	Retrospective cohort study 6 years	CPOE	36103 patients 36103 discharges	Paediatrics	There was 43% reduction in rate of prescription errors. No p value was given.
Mahoney et al., (2007) (USA)	2 Private Academic hospitals (247 and 719) bed Hospital wide	Retrospective pre-post CPOE Pre implementation and post implementation periods were 12 months in duration.	CPOE+ CDSS	1,452,346 orders in the Pre implementation period and 1,390,789 orders in the post implementation period	Both	Prescribing errors reduced significantly in three out of four monitored categories, specifically drug allergy reporting, excessive dosing and incomplete or unclear orders $p < 0.001$. A non-significant reduction was recorded in therapeutic duplication.
Mendendez et al., (2012) (Spain)	1 Academic hospital 200 bed hospital wide	Retrospective pre-post CPOE six years	CPOE	18348 patients	Adults	Prescribing errors increased 10 folds with electronic prescribing system no p value given. Prescribing errors per discharge was higher after CPOE implementation from 5.1% to 10.5% (2.1 times more frequent).
Oliven et al., (2005) (Israel)	Two 44-beds general medical wards one with handwritten medication orders, the second with CDOE	Prospective cohort study two medical units. Six months	CDOE	HW ward : 641 patients CDOE ward: 709 patients	Adults	There was a significant reduction of prescribing errors after introducing electronic prescribing system. Wrong dose or interval reduced −81.80% p <.001. Error in drug interaction reduced −50% p <0.01. Drug–laboratory interaction reduced −64% p <.001.
Potts et al., (2004) (USA)	1 Academic tertiary care hospital 20 bed multidisciplinary paediatric critical care unit	Prospective study comparing pre / post implementation of CPOE; review of all medication. 2 months before CPOE 2 months after CPOE	CPOE	Total number of patients 514 patients 268 patients pre-CPOE (6803 orders). 246 patients post-CPOE (7025 order).	Paediatrics	The rate of prescribing errors reduced significantly from 39.1 errors per 100 orders to 1.6 errors per 100 orders ($P < 0.001$).
Redley and Botti (2012)[Redley and Botti, 2013] (Australia)	2 private hospitals Hospital-wide Hospital 1 (520) bed Hospital 2 (223) bed	Retrospective analysis of incidence report in both hospitals. 1 year	Medication management system	Not stated	Adults	Prescribing errors rate was relatively high proportion (31.1%) in site 2 which uses electronic prescribing system in contrast to only 7.9% of this error type at Site 1 which uses traditional prescribing method.
Shawahna et al., (2011) (Pakistan)	1 teaching hospital 1280 bed Hospital wide	Prospective review of medication and discharge medication charts before and after the introduction of an electronic inpatient record and prescribing system. 5 days.	Electronic inpatient record and prescribing system	Inpatient records (n = 3300) 1100 discharge medication sheets	Both	Prescribing errors reduced significantly by introduction of electronic prescribing system from 22.6% to 8.2% ($p < 0{\cdot}01$).

Source/ Country	Setting	Study design/length of study	Intervention	Number of patients and prescription (n)	Adult/Paediatric	Outcomes and findings
Shulman et al., (2005) (UK)	1 teaching hospital 22-bed Intensive Care unit	Prospective before and at several time points after implementation of CPOE. 70 weeks.	CPOE	1036 prescriptions during hand writing stage 2429 prescriptions during electronic prescribing stage	Adults	A significant reduction in the prescribing error rate from 6.6 to 4.7% (relative reduction 28.8%). ($p< 0.04$).
Spencer et al., (2005) (USA)	1 academic hospital. Two general medicine floors	Observational time series study of prescribing errors voluntary report. 16 months.	CPOE	Not stated clearly 2 818 180 items in computerized and 2 028 770 prescription items in hand written prescriptions	Adults	Prescribing errors rates increased from 0.068 to 0.088 error per discharge (a 27% overall increase).
Van Doormal et al., (2009) (Netherlands)	2 academic hospitals 2 medical wards at each hospital	Interrupted time-series Total time period 10 months 5 months pre-implementation 5 months post-implementation	CPOE/CDSS	7286 orders pre-intervention 7058 orders post-intervention	Adults	A significant reduction in the prescribing error rate after implementing electronic prescribing system -30% [95% CI: 35%, 25%]).
Vélez-Díaz-Pallarés et al., (2011) (Spain)	1 tertiary hospital 2 trauma units with 28 beds each	Prospective, descriptive, observational 45 days	Electronically assisted prescriptions	Total number of patients: 163 patients (393 orders) 212 electronic medical orders 181 manual medical orders	Adults	Prescription errors decreased by 53% with electronic system. The rate of error decreased from 19.5 to 9.4%.
Voeffary et al., (2006) (Switzerland)	1 university Hospital multidisciplinary oncology centre	Prospective, controlled time series study Total time period 36 months 15 months pre-implementation 21 months post-implementation	CPOE	1467 handwritten prescriptions 978 computerised prescriptions	Adults	A significant reduction in the rate of prescribing error from 13.1 to 0.6% of medication orders per month in the handwritten and electronic prescription groups respectively (relative reduction 96%).
Walsh et al., (2008) (USA)	1 teaching hospital 4 PICU beds, 15 NICU beds, and 40 surgical and medical paediatric ward beds.	Interrupted time-series regression analysis all charts, orders, and incident reports for 40 admissions per month Total time period 16 months 7 months pre-implementation 9 months post-implementation	CPOE	627 admissions 12672 orders	Paediatrics	No statistically significant change in the incidence of serious ordering errors after CPOE compared with before CPOE. The intervention was not show a reduction in dosing errors.
Warrick et al., (2011) (UK)	PICU in an NHS without further details.	Prospective pre-post audit study 96 hours periods in three epochs 2 weeks before implementation 1 week after implementation 6 months after implementation	Electronic prescribing (EP) with a clinical information system	54 charts 624 prescriptions	Paediatrics	There was no clinically significant change in the incidence of prescribing errors across the three periods. The rate of prescribing errors was 4.6%.

Source/ Country	Setting	Study design/length of study	Intervention	Number of patients and prescription (n)	Adult/Paediatric	Outcomes and findings
Weant et al., (2007) (USA)	1 hospital (type not stated) neurosurgical ICU	Retrospective cohort analysis of voluntarily reported medication-error reports. 26 month in total 23 pre-implementation and 10 weeks post-implementation	CPOE	Not stated	Adults	The number of ordering errors increased after the introduction of electronic prescribing system more than reported during the same month the previous year (n = 27 versus 6; p = 0.039) (0.938 versus 1.839 per 1000 doses).
Went at al., (2010) (UK)	1 Teaching Hospital ICU 10-bed	Retrospective review of paper charts and electronic charts.	Electronic prescribing and administration system	329 electronic prescriptions 408 paper based prescriptions	Adults	A significantly reduction in prescribing errors rate in electronic prescriptions (8.5%) compared with handwritten prescriptions (51%).
Westbrook et al., (2012) (Austalia)	2 teaching hospitals Hospital A: 4 wards (two geriatric, a renal/vascular, and a respiratory ward). geriatric) Hospital B: two wards (psychiatry and cardiology).	Controlled before–after Hospital A: 4 months pre intervention and 4 months post intervention. Hospital B:5 months pre-intervention and 12 months post-intervention.	CPOE+CDSS	3,291 medication charts 1,923 at baseline and 1,368 post e-prescribing system.	Adults	A Significant reduction in prescribing error rates fell significantly at both hospitals following intervention ($p<0.0001$).
Wetterneck et al., (2011) (USA)	1 teaching hospital 2 intensive care units (AICU and CICU) (24 and 18-bed respectively)	Prospective pre and post observational study 30 weeks pre-intervention 25 weeks post-intervention	CPOE+CDSS	630 patients pre-CPOE (45,658 orders) 625 patients post-CPOE (32,841 orders)	Adults	The number of duplicate medication orders increased after CPOE implementation (pre: 48 errors, 1.16 errors/100 patient-days; post: 167 errors, 4.16 errors/100 patient-days; $p<0.0001$).

2.3.3 Impact of E-prescribing systems on prescribing errors

Variable levels of sophistication of e-Prescribing systems were described in the studies. These ranged from a basic electronic reference of medications which provided clinicians with a drop-down menu to support the prescribing decisions to an advanced system which had decision support features. These features included automatic checking for duplication or incorrect doses, provision of alert messages highlighting deviations from the standard therapy pathway, interactions with other medications, or illustration of clinical guidelines to improve evidence-based treatment.

The majority of studies (76%, 29/38) demonstrated a significant reduction on the incidence of prescribing errors associated with electronic prescribing systems, however, 16% (6/38) showed that electronic prescribing systems resulted in an increased rate of prescribing errors (Evans et al., 1998, Menendez et al., 2012, Redley and Botti, 2013, Spencer et al., 2005, Weant et al., 2007, Wetterneck et al., 2011). Four of those that showed increases in rates, studies' data were analysed from errors that were submitted using voluntary reporting of prescribing errors (Menendez et al., 2012, Redley and Botti, 2013, Spencer et al., 2005, Weant et al., 2007), a method likely to result in under-reporting of errors. Three studies revealed that introduction of computerised prescribing systems were not associated with a significant change in error rate (Choo et al., 2014, Walsh et al., 2008, Warrick et al., 2011).

2.3.3.1 Paediatric

Twelve studies examined the impact of electronic prescribing systems with varying levels of clinical decision support on prescribing error rates in paediatric patients (Cordero et al., 2004, Fontan et al., 2003, Holdsworth et al., 2007, Jani et al., 2010, Jozefczyk et al., 2013, Kadmon et al., 2009, Kazemi et al., 2011, Kim et al., 2006, King et al., 2003, Potts et al., 2004, Walsh et al., 2008, Warrick et al., 2011). Four of these studies included both children and adults (Barber, 2006, Collins and Elsaid, 2011, Mahoney et al., 2007, Shawahna et al., 2011).

More than half of the paediatric studies (58%, 7/12) were conducted in paediatric intensive care units (Cordero et al., 2004, Holdsworth et al., 2007, Jozefczyk et al., 2013, Kadmon et al., 2009, Potts et al., 2004, Walsh et al., 2008, Warrick et al., 2011). Most of these demonstrated significant reductions in the incidence of prescribing errors, however, two studies indicated

that electronic prescribing systems had no effect on the occurrence of dosing errors (Holdsworth et al., 2007, Walsh et al., 2008).

Of five studies conducted in paediatric standard care with prescribing errors as an outcome measure, electronic prescribing conferred a significant beneficial effect in three (Fontan et al., 2003, Kazemi et al., 2011, Kim et al., 2006), whereas, a non-significant or no beneficial effect was reported in the other two (Jani et al., King et al., 2003).

2.3.3.2 Adults

Sixteen studies conducted in adult settings (16/22, 73%) found that there was a significant reduction in the incidence of prescribing errors associated with the use of computerised order entry. Spencer and co-workers (2005) stated that there was a non-significant reduction in the rate of prescribing error per discharge following electronic prescribing implantation (Spencer et al., 2005). Six of these studies (6/22, 27%) revealed that the introduction of computerised prescribing was associated with an increase or no effect on the level of prescribing errors (Choo et al., 2014, Evans et al., 1998, Menendez et al., 2012, Redley and Botti, 2013, Weant et al., 2007, Wetterneck et al., 2011).

2.3.4 Meta-analysis

A meta-analysis was conducted to pool the prescribing errors. Of the 38 studies, 32 were eligible for the pooled analysis; ORs ranged from 0 to 6.27. Overall, electronic prescribing systems were associated with a 74 percent reduction in prescribing errors (OR=0.26; 95% CI 0.16-0.42) (Figure 2.2). There was evidence of heterogeneity between studies (I^2= 99%) owing to intervention factors. Overall, electronic prescribing systems were associated with a reduction of prescribing errors based on the random effects model.

However, five studies included in the pooled analysis reported increases in the incidence of prescribing errors after the implementation of electronic prescribing systems. Among these studies, two analysed prescribing errors that were reported using a voluntary reporting system by staff members (Menendez et al., 2012, Spencer et al., 2005). This kind of error detection method could lead to under-reporting of errors, which limit reliability.

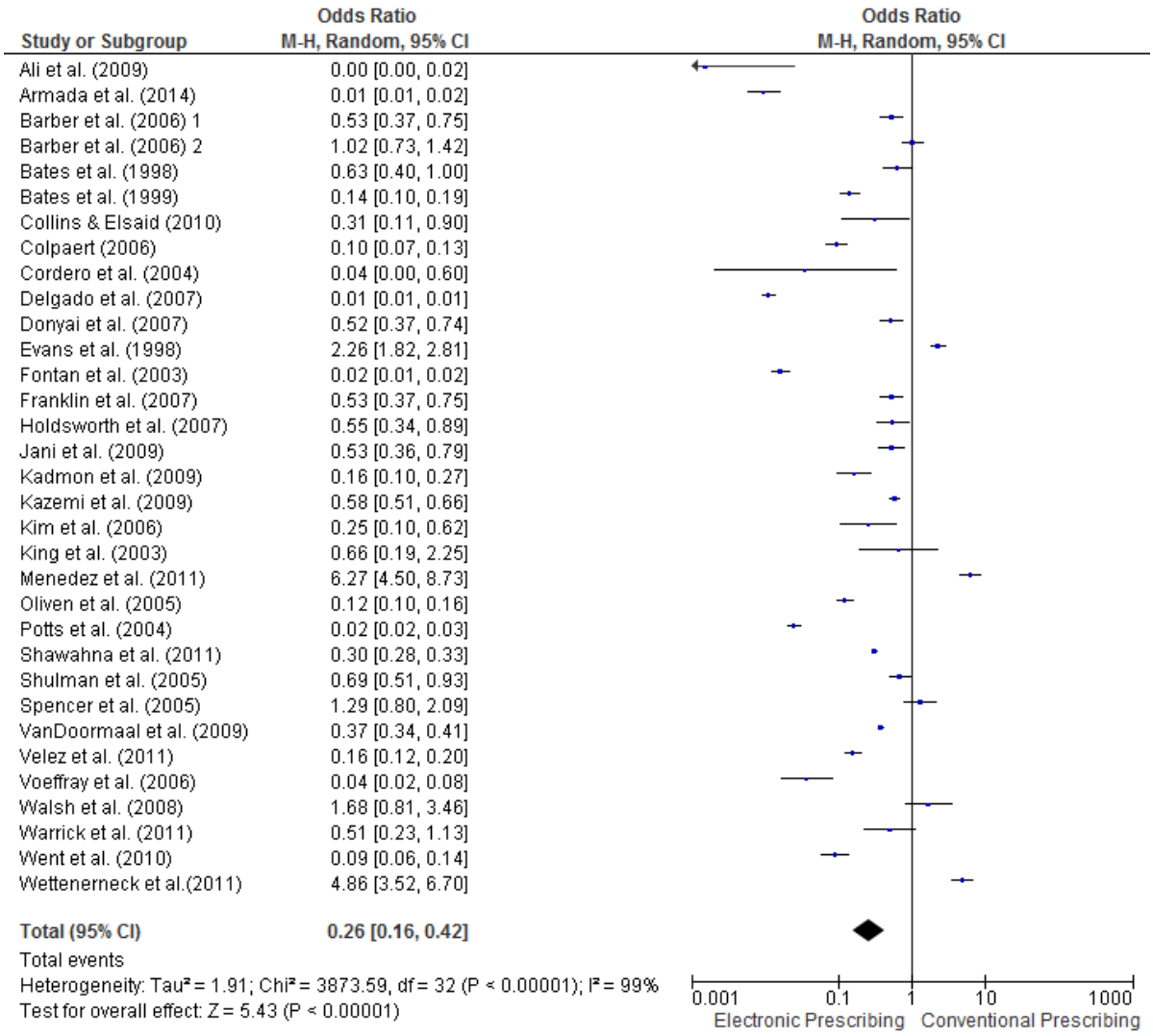


Figure 2.2. Forest plot of prescribing errors with electronic prescribing compared with conventional prescribing systems.

A sub-group analysis comparing prescribing error reduction by commercial systems versus home-grown systems indicated a higher reduction by home-grown systems but this difference was not statistically significant (home grown 0.17 [0.06, 0.45] versus commercial 0.28 [0.12, 0.66]) (Figure 2.3).

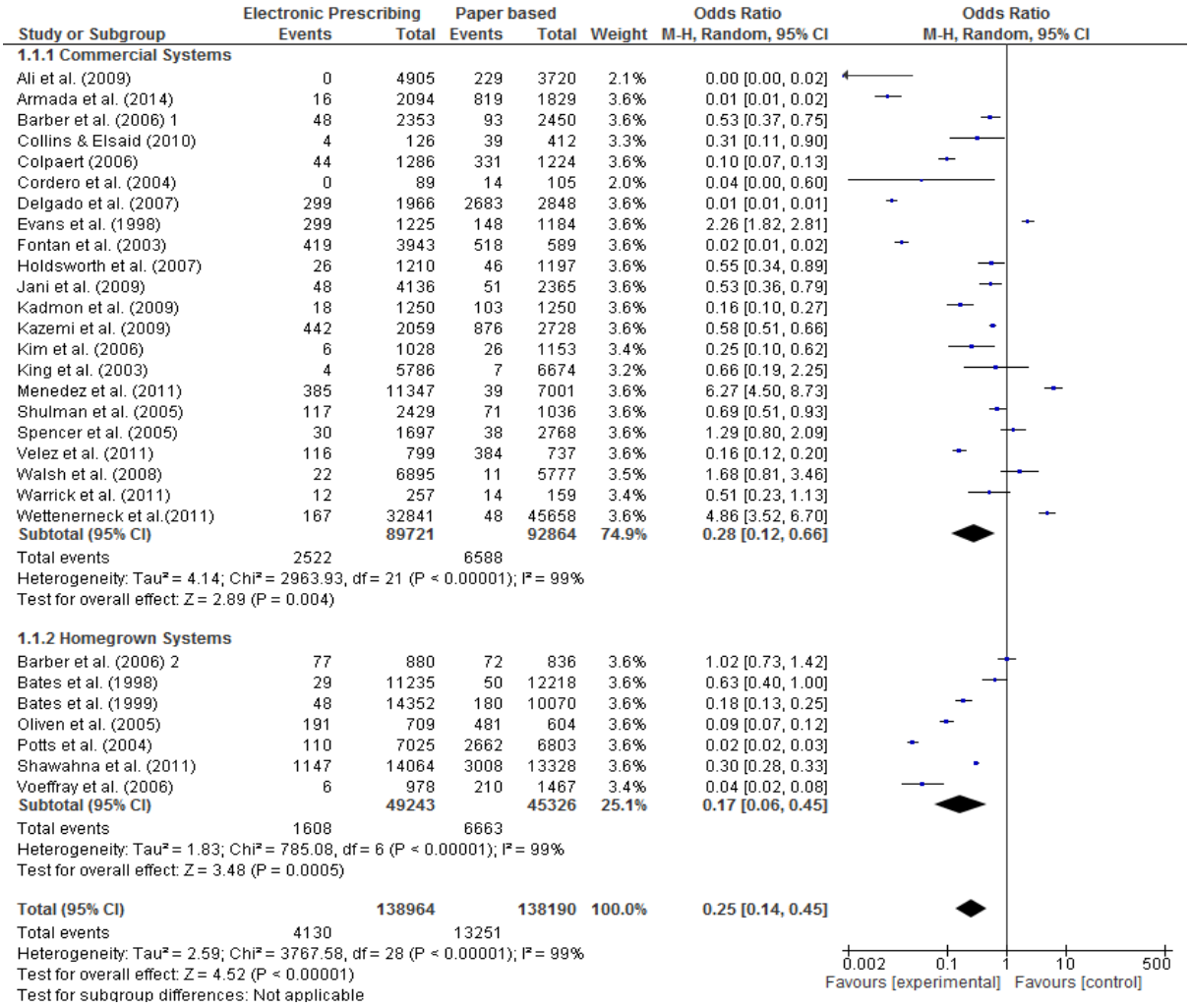


Figure 2.3. Forest plot of prescribing errors comparing commercial with home grown prescribing systems.

Sub-group analysis revealed that systems with advanced decision-support appear to have higher impact on the reduction of prescribing errors compared with basic and moderate levels of functionality. The 9 studies with an advanced decision-support reported higher prescribing error reduction than the 18 studies with limited or no decision-support (advanced 0.16 [0.06, 0.47] versus basic or limited 0.24 [0.12, 0.47]). However, the difference was not significant. (Figure 2.4).

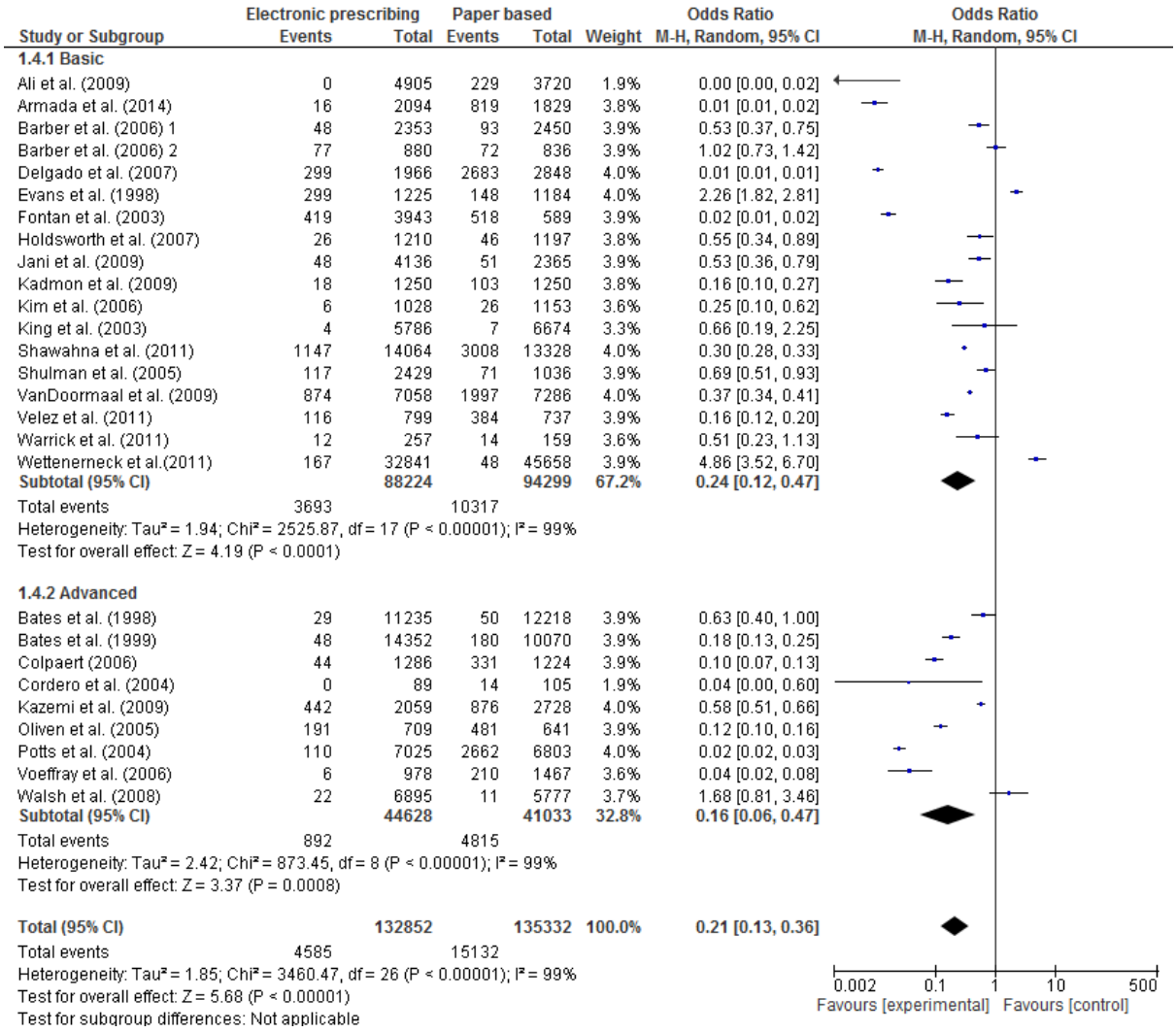


Figure 2.4. Forest plot of prescribing errors comparing basic and advanced prescribing systems.

2.3.5 Severity of prescribing errors following electronic prescribing systems

The severity of prescribing errors following the deployment of electronic prescribing systems was assessed in five studies (Colpaert et al., 2006, Donyai et al., 2008, Franklin et al., 2007, Shulman et al., 2005, Voeffray et al., 2006). The severity of prescribing errors scale is an index that ranges from 0 (no harm) to 10 (death) (Dean and Barber, 1999). Shulman and co-workers (2005) identified three classes of severity (minor, moderate, major), however, this study did not define these categories. Colpaert and co-workers adopted a numerical scale of 0-6; all categories were defined in terms of severity. Furthermore, Voeffray and co-workers reported errors as either minor or major errors, but the definitions of these errors were inconsistent with established scales such as those described by Dean and co-worker (1999).

Colpaert and co- workers reported that before electronic prescribing implementation, 60 major prescribing errors were found in 1224 medication orders (4.9%). After system implementation, 23 major prescribing errors were found in 1286 orders (1.8%). This emphasized a significant reduction in major prescribing errors in medication orders. However, before electronic prescribing system implementation, 60 out of 331 errors (18%) were classified as major severity, as opposed to 23 out of 44 errors (52%) after the system deployment. This showed a significant increase in the amount of major errors, which indicates a corresponding reduction in the proportion of minor errors post electronic prescribing system (Colpaert et al., 2006).

Shulman and co-workers reported 19 moderate / major errors in 1,036 hand written medication orders (1.8%) in comparison to 22 out of 2,429 (0.9%) electronic medication orders. This evidently shows a significant reduction in the overall number of errors in medication orders. 19 of 69 errors (28%) in the hand-written orders were moderate to major, whereas 22 out of 117 (19%) were moderate to major in the electronic orders. However, this reduction in errors was not deemed significant (Shulman et al., 2005).

Franklin and co–workers (2007) reported in their study there was no statistical difference in the mean severity of prescribing error scores before and after electronic prescribing system implementation. Voeffray and co-workers (2006) reported that 19% (27 out of 141) of prescribing errors were categorised as "major" before the implantation of electronic prescribing system, and 81% (114 out of 141) were "minor". After the implementation of an electronic prescribing system, all 6 errors identified were categorised as minor.

2.3.6 Incidence of prescribing errors in electronic systems

Examination of the review studies showed the use of a range of different denominators to evaluate prescribing error rates. These included medication orders, admissions, patient days and doses. Some studies used more than one denominator to represent error rates: the present review analysed each denominator separately in this report. Heterogeneity in error detection methods was also varied across studies included.

Several studies (63%, 24/38) reported the rate of erroneous medication orders, the median of which was 3.4% (IQR 1.5-8.8%) of medication orders. Four studies did not state the total number of medication orders when reporting the rate of errors and could not, hence, be included in this median error rate calculation (Ali et al., 2010, Choo et al., 2014, Evans et al., 1998, Redley and Botti, 2013).

Six studies described error rates per 1000 patient days, the median of which was 4.5 (IQR 2.5-118) errors per 1000 patient days.

Five studies showed a rate of error per admission, the median of which was 6.7 (IQR 2.4-96) errors per 100 admissions. This wide range in error rates could be attributed to the use of different methods of error detection: the lowest rate (0.8 errors per 100 admissions) being taken from a voluntary reporting form (Spencer et al., 2005) and the highest was 136 errors per 100 admission resulting from a daily review of inpatient medical charts (Westbrook et al., 2012).

Subgroup analysis of studies showed that the rate of erroneous orders was more common in adult than in paediatric settings (median 4.8% [thirteen studies, IQR 2-9.4% versus median 2.3% [eight studies IQR 0.7-6.1%]).

2.3.7 Types of prescribing errors

Inconsistencies were detected in the reported type of prescribing errors. For example, prescribing errors were considered in some studies as medication errors arising during the prescribing phase. This is due to authors' choice of definition and classification of prescribing errors being used in the included studies.

Various definitions of prescribing errors were employed in the identified review papers (92%, n = 35). One study focused on duplication medication ordering error (Wetterneck et al., 2011) and another failed to state the type of error investigated (King et al., 2003).

Dosing error was the most common type of reported of prescribing error (84%, 32/38) (Armada et al., 2014, Barber, 2006, Bates et al., 1998, Bates et al., 1999b, Choo et al., 2014, Collins and Elsaid, 2011, Colpaert et al., 2006, Delgado Silveira et al., 2007, Donyai et al., 2008, Evans et al., 1998, Fontan et al., 2003, Franklin et al., 2011, Holdsworth et al., 2007, Jani et al., 2010, Jozefczyk et al., 2013, Kadmon et al., 2009, Kazemi et al., 2011, Kim et al., 2006, Mahoney et al., 2007, Menendez et al., 2012, Oliven et al., 2005, Potts et al., 2004, Redley and Botti, 2013, Shawahna et al., 2011, Shulman et al., 2005, van Doormaal et al., 2009a, Vélez-Díaz-Pallarés et al., 2011, Walsh et al., 2008, Warrick et al., 2011, Went et al., 2010, Westbrook et al., 2012), of which one focused on dosing errors in the paediatric setting (Jani et al., 2010). The dosing type of error included dose calculation errors, unit error or trailed zero errors. Errors involving wrong medication and route errors were the next most common (47%, 18/38) (Armada et al., 2014, Barber, 2006, Bates et al., 1998, Bates et al., 1999b, Choo et al., 2014, Colpaert et al.,

2006, Delgado Silveira et al., 2007, Donyai et al., 2008, Fontan et al., 2003, Mahoney et al., 2007, Menendez et al., 2012, Potts et al., 2004, Shawahna et al., 2011, Shulman et al., 2005, Vélez-Díaz-Pallarés et al., 2011, Voeffray et al., 2006, Weant et al., 2007, Westbrook et al., 2012) and were caused by a wrong selection from a drop down menu or as a result of a wrong predefined route default. Errors involving dosage interval was also a common type of prescribing error (39%, 15/38) (Armada et al., 2014, Bates et al., 1998, Bates et al., 1999b, Choo et al., 2014, Delgado Silveira et al., 2007, Donyai et al., 2008, Jozefczyk et al., 2013, Kadmon et al., 2009, Kazemi et al., 2011, Oliven et al., 2005, Potts et al., 2004, Shawahna et al., 2011, Vélez-Díaz-Pallarés et al., 2011, Weant et al., 2007, Westbrook et al., 2012).

The remaining error types were drug allergies (21%, 8/38) (Bates et al., 1998, Choo et al., 2014, Colpaert et al., 2006, Jozefczyk et al., 2013, Mahoney et al., 2007, Spencer et al., 2005, Vélez-Díaz-Pallarés et al., 2011, Westbrook et al., 2012) errors caused by missing documentation of patient allergy status, duplication order errors (21%, 8/38) and wrong formulation errors (16% 6/38) (Barber, 2006, Donyai et al., 2008, Fontan et al., 2003, Franklin et al., 2007, Shawahna et al., 2011, Westbrook et al., 2012).

Completeness of prescriptions in which a medication had been ordered but the prescription had some missing elements such as route of administration, dosage form or dosage interval was reported in some studies as a type of prescribing error (Evans et al., 1998, Shawahna et al., 2011, Went et al., 2010, Westbrook et al., 2012). The least common of error type was a medication duration error, examined in only one study (Delgado Silveira et al., 2007).

2.3.8 Medications associated with prescribing errors

Differences in the reporting of medications among studies were apparent; some studies involved the medication names, and others listed only the therapeutic classes involved.

Seventeen studies (45%) provided details about the specific named medications associated with prescribing errors. Twelve studies reported the medications or therapeutic classes that were associated with the incidence of prescribing errors (Armada et al., 2014, Bates et al., 1998, Colpaert et al., 2006, Evans et al., 1998, Fontan et al., 2003, Holdsworth et al., 2007, Menendez et al., 2012, Redley and Botti, 2013, Shawahna et al., 2011, Shulman et al., 2005, Vélez-Díaz-Pallarés et al., 2011, Wetterneck et al., 2011). Five studies specifically examined antineoplastic

agents as a therapeutic class only (Collins and Elsaid, 2011, Cordero et al., 2004, Kim et al., 2006, Mahoney et al., 2007, Voeffray et al., 2006).

Most of the prescribing errors in studies conducted on adult patients involved antimicrobials (Bates et al., 1998, Colpaert et al., 2006, Evans et al., 1998, Fontan et al., 2003, Holdsworth et al., 2007, Menendez et al., 2012, Redley and Botti, 2013, Shawahna et al., 2011, Shulman et al., 2005, Vélez-Díaz-Pallarés et al., 2011, Wetterneck et al., 2011), cardiovascular drugs (Armada et al., 2014, Bates et al., 1998, Colpaert et al., 2006, Evans et al., 1998, Fontan et al., 2003, Menendez et al., 2012, Redley and Botti, 2013, Shulman et al., 2005, Wetterneck et al., 2011)or analgesic medications (Bates et al., 1998, Evans et al., 1998, Holdsworth et al., 2007, Redley and Botti, 2013, Shawahna et al., 2011, Shulman et al., 2005, Vélez-Díaz-Pallarés et al., 2011, Wetterneck et al., 2011). In addition, prescribing errors reported in studies conducted in paediatric settings found that analgesics, antibiotics, antineoplastic agents and immunosuppressant medications were the most common drugs associated with prescribing errors (Fontan et al., 2003, Holdsworth et al., 2007).

One study specifically examined intravenous (IV) medications fluids, IV drug infusions and intermittent (regular/ PRN) drugs and found that 32% of prescriptions had no reference to a diluent (Evans et al., 1998).

2.4 Discussion

2.4.1 Main findings

The present systematic review provides evidence that the use of an electronic prescribing system is associated with a significant reduction of prescribing errors in adult and paediatric settings. The meta-analysis in this review affirmed this finding. The pooled analysis is conclusive that an electronic prescribing system is associated with up to a 77% reduction in prescribing errors. It follows that by preventing the occurrence of some prescribing errors, patients' safety will be improved and outcomes enhanced. This finding is in line with other reviews that examined the impact of using computerised systems on the risk of prescribing errors (Ammenwerth et al., 2008, Shamliyan et al., 2008).

Furthermore, the significant reduction in the incidence of prescribing errors following implementation of electronic prescribing systems was not surprising. The automation and

standardisation of the format structure of electronic medication orders intrinsically remove some error types, for example, legibility errors. Eliminating these types of errors is paramount, however, the greater challenge resides in enabling suitable, evidence-based care. In this, the application and use of electronic prescribing systems that include sophisticated levels of decision support applications are estimated to have an immense effect on the reduction of errors and adverse outcomes.

With regards to the studies included, limited conclusions can be drawn about changes in prescribing error severity following electronic prescribing systems implementation. Only 5 of 38 studies included assessed severity of errors, but only two studies defined, in depth, the scale of severity. A majority of studies referred to the data that implied that electronic prescribing systems effectively improved a reduction of prescribing errors. However, a direct conclusion cannot be made as to whether electronic prescribing systems are effective at reducing severe prescribing errors, this should be a focal point for future research.

The data from four studies were analysed from errors that were submitted using voluntary reporting of prescribing errors (Menendez et al., 2012, Redley and Botti, 2013, Weant et al., 2007, Spencer et al., 2005). Voluntary reporting systems, such as those used in pharmacovigilance, are known to have high levels of under-reporting (Hazell and Shakir, 2006). The introduction of the computerised prescribing system is likely to have led to heightened vigilance for errors in this case, and a higher reporting rate, rather than a higher rate of absolute prescribing errors.

There were no statistically significant differences in effect between commercial and home-grown systems, with or without decision support of different sophistication levels. This result is in line with a systematic review which examined the effectiveness of different types of systems on medication errors (Nuckols et al., 2014).

The finding from this systematic review quantified that the incidence of prescribing errors associated with electronic prescribing systems had a median error rate of 3.4% (IQR 1.5-8.8%) of medication orders, 4.5 (IQR 2.5-118) errors per 1000 patient days and 6.7 (IQR 2.4-4.96) errors per 100 admissions. Prescribing errors were about half as common with electronic prescribing systems as with hand written prescribing methods, and reduction of error was similar across included studies with varied factors; intervention, implementation, methodological and contextual factors. In a systematic review conducted by Lewis and co-workers (2009) the median error rate (interquartile range [IQR]) was 7% (2–14%) of

medication orders, 52 (8–227) errors per 100 admissions and 24 (6–212) errors per 1000 patient days (Lewis et al., 2009). Subgroup analysis in the present review has yielded the interesting finding that adult prescribing appears to be associated with twice the error rate observed in paediatric settings. The rate of erroneous orders errors was also more common in adult than in paediatric settings (median 4.8% [thirteen studies, IQR 2-9.4% versus median 2.3% [eight studies IQR 0.7-6.1%]). Reasons for this might include, greater caution in prescribing in children, more experienced prescribers being allowed to prescribe to children, or a more limited range of drugs being prescribed in the paediatric population.

The most common type of prescribing errors found to be associated with using electronic prescribing systems are: dosing error, frequency errors and medication selection errors. This result has been found in line with a systematic review by Reckman and co-workers (2009). These types of errors could be explained by inappropriate selection from drop down menus, or erroneous selection of default doses. Several studies examining the use of electronic prescribing systems have reported that the use of drop-down menus is a major challenge that easily results in unintended selection error (Campbell et al., 2006, Palchuk et al., 2010, Smith et al., 2009).

The implementation of computerised prescribing systems appears to have introduced a different type of error compared to those experienced with traditional paper systems. These include selection of an inappropriate dosage form for an intended route (e.g., capsules instead of intravenous administration), selection of a wrong product (Mahoney et al., 2007), wrong dose, frequency, or dosage form from a dropdown menu (Shulman et al., 2005), inappropriate use or modifying of default doses (Donyai et al., 2008), failing to document the status to a drug allergy (Spencer et al., 2005) and failure to discontinue a medication no longer needed (Evans et al., 1998). As electronic prescribing systems appear to be associated with the introduction of new types of error, clinicians should be vigilant when ordering medications using such systems. Little discussion can be found in most papers regarding the development of methods to identify new types of errors associated with electronic prescribing systems. Therefore, the present results provide a rigorous base to initiate research on the impact of electronic prescribing system design on the incidence of prescribing errors.

Antimicrobial, cardiovascular and analgesic agents were the most common therapeutic agents associated with prescribing errors in adults. For children, antibiotics were agents most associated with prescribing errors. Overall, antimicrobial medications were the common

therapeutic class associated with errors. This finding was similar to a systematic review that evaluated prescribing errors in paper based systems, which showed that antimicrobial agents were associated with the most prescribing errors (Lewis et al., 2009). Therefore, it is likely that the implementation of antimicrobial stewardship, where not already instituted, could optimise appropriateness of prescribing practice of antimicrobial agents.

The association between electronic prescribing systems implementation and prescribing errors showed vast heterogeneity across the included studies. This variability could be attributed to three factors; intervention factors, contextual factors and methodological factors. Intervention factors include how the electronic prescribing systems were designed and implemented, contextual factors involve differences in patient populations and settings, and finally, methodological factors include differences in study design and executions (Deeks et al., 2008).

Variations in the reported rates of prescribing errors across studies can be due to varied definitions of prescribing error along with differing methods of data collection. Sixty percent of studies used their own definition or did not state a definition used. In an attempt to address this issue a prescribing error definition has been developed by Dean and co-workers (Dean et al., 2000). However, such definition was only used in 13% of all studies (5/38, 13%). Method of detection is also important, Franklin and co-workers (2009) found different rates of prescribing errors when comparing four different methods in the same patients (Franklin et al., 2009). Similarly Franklin and co-workers showed that the incidence of errors is highly dependent on the detection method: prospective methods of data collection by ward pharmacists appeared best for research purposes (Franklin et al., 2009).

2.4.2 Strengths

The present study appears to be the first systematic review that combines evaluation of the impact of electronic prescribing systems on prescribing errors with quantification of the incidence and nature of electronic prescribing errors in inpatient settings. This systematic review has applied a robust systematic review search technique using a variety of databases to identify the relevant studies. The findings from this review have importance for health care professionals, practice, health care policy makers and research.

2.4.3 Limitations

The present systematic review could be limited by including English language publications only, resulting in the omission of non-English relevant publications. The reported rates of error could be affected by the sub-type of prescribing errors reported in some studies. Such studies may have focused only on a sub-type prescribing error such as dosing errors (Jani et al., 2010) or duplication errors (Wetterneck et al., 2011). Also, the present review could be augmented by considering the post implementation period of electronic prescribing systems when evaluating the studies.

2.5 Conclusions

The present study showed that electronic prescribing systems generally are effective interventions for reducing the risk of prescribing errors in hospitalised patients, thus intuitively improving patient safety. Implementing an electronic prescribing system is associated with a greater than 75% decline in prescribing error rates in hospital-related settings. The present review found that there is no difference between commercial and home grown systems, with or without clinical decision support. Research review showed lack of standardized definitions and scales of severity when it came to identifying prescription errors. Different study designs, such as prospective and retrospective, and methods of detecting errors, e.g., incidence reports and observations, gave different results on the nature of prescription errors. Therefore, it is important future research adopts more standardized definitions of prescription errors to allow more consistent results.

3 Chapter 3: Reducing prescribing errors associated with inpatient electronic prescribing systems: an investigation of pharmacist interventions to prevent prescribing errors

3.1 Introduction

Improving patient safety in general, and the reduction in prescribing errors in particular, has been a major source of concern internationally (Scobie et al., 2005). Prescribing errors are common types of medication errors which include prescribing, dispensing, administration, and monitoring errors (Cousins et al., 2007). In an international systematic review, prescribing errors affected 50% of hospital admissions and 7% of medication orders (Lewis et al., 2009). In the UK, two studies conducted in up to 20 hospitals found that the prescribing error rates were 8.8% and 10.9% of prescribed medications (Ashcroft et al., 2015, Seden et al., 2013). It has been reported that the National Reporting and Learning System (NRLS) in England and Wales received 526,186 medication incident reports between 1 January 2005 and 31 December 2010 (Cousins et al., 2012). Of these medication incident reports, 75% occurred in acute general hospitals. Such errors can increase the length of hospital stay and increase patient morbidity (Ben-Yehuda et al., 2011, Classen et al., 1997). In England, medication errors could cost the NHS more than £750 million annually (Cousins et al., 2007).

In the UK, electronic prescribing systems have been proposed to reduce prescribing errors and improve patient safety in hospitals (Department of Health, 2007). Such systems have shown to reduce prescribing errors, however, they might introduce some new type of errors (Birdsey et al., 2005, Estellat et al., 2007, Fowlie et al., 2000, Vira et al., 2006). Therefore, it is vital to examine these systems to ensure that they improve patient safety in the absence of unintended consequences. Previous research involves studies examining electronic prescribing systems in secondary care are predominantly from United States (Ash et al., 2009, Campbell et al., 2006, Jayawardena et al., 2007, Shamliyan et al., 2008, Spencer et al., 2005). However, clinical practice and electronic prescribing systems differ in the UK (Brock and Franklin, 2007, Stebbing et al., 2006).

In the UK, few studies have examined the relationship between pharmacists' interventions and prescribing errors in the context of an electronic prescribing system (Abdel-Qader et al., 2010, Donyai et al., 2008). However, these studies have focussed in one case on a surgical ward and on discharge medication in the other. The present study was intended to investigate prescribing errors detected by clinical pharmacists in patients within a large teaching hospital operating a well-established home-grown electronic prescribing system.

The aim of the present study was to examine the number, types, and severity of prescribing errors documented by hospital pharmacists within an electronic prescribing system and their role in identifying and preventing prescribing errors.

3.2 Objectives

To perform a retrospective analysis of interventions reported in the PICS system by hospital pharmacists to:

- Quantify the proportion of pharmacist interventions in PICS that relate to prescribing errors.
- Compare the incidence, characteristics and severity of prescribing errors made by prescribers.
- Determine the medications and therapeutic classes associated with sub-optimal prescribing.
- Determine the specialities of the wards associated with prescribing errors.

3.3 Methods

3.3.1 Study site

The study was carried out in University Hospital Birmingham NHS Foundation Trust (UHBFT). It is one of the highest performing hospital across Europe with high standards of the quality of care, information technology, training and research (UHBFT, 2018). UHBFT has 1,213 inpatient beds, 32 operating theatres and a 100-bed critical care unit, which is the largest co-located critical care unit in the world. The study site is the leading centre in solid organ transplantation in Europe, cancer management as well as the second largest centre in the UK for renal dialysis. UHBFT provides numerous medical and surgical specialities and is highly

specialised cardiac and liver services. It is recognised as a major specialist centre for burns and plastic surgery. It has proven international reputation for its quality of care, information technology, clinical education and training and research. Recently, the trust has been acknowledged as one of the most successful NHS foundation trusts (UHBFT, 2018).

3.3.2 Electronic Prescribing System

University Hospitals Birmingham operates a home grown electronic prescribing system known as "patient information communication system" (PICS). The system was developed by a team including physicians, pharmacists and informatics experts. It is an advanced electronic prescribing system which is integrated to clinical decision support features. These features include dose range checking, drug interactions alerts and contraindications (e.g. drug–disease, allergies). The system operates in inpatient, outpatients and day care wards. The system supports prescribing and drug administration for all kinds of medications including chemotherapy medication orders. The system also operates laboratory requests and results, clinical observations and assessments, as well as communications including imaging results and internal referrals. PICS is used by all prescribers at the site to prescribe for all 1213 inpatients. The system has over 4,000 registered users, manages 25,000 new prescriptions and 125,000 drug administration events a week.

3.3.3 Definitions:

Before conducting the study, it was important to define a number of operational definitions to ensure that data was collected to standard specifications. These definitions and their derivations are set out below:

3.3.3.1 Medication order

Any medication ordered electronically by an authorized healthcare prescriber along with its specific characteristics (correct drug name, dose, dosage form, frequency, route of administration, direction of use, and duration of treatment).

The authorised health care prescribers at UHBFT are:

- Physicians (different grades)
- Dentists
- Non-medical prescribers (pharmacist, nurse, optometrist, and physiotherapist).

3.3.3.2 Pharmacists' clinical intervention

This is defined as:

"any reactive (in response to an erroneous medication order) activity undertaken to suggest changes in one medication order that might involve contacting medical staff" (Abdel-Qader et al., 2010).

These interventions were classified into two categories: interventions associated with prescribing error(s) and interventions not associated with prescribing error(s). Some interventions endorsed by pharmacists are related to errors in dispensing, administering or monitoring medications or the patient. These interventions were excluded as they are beyond the scope of the present study.

3.3.3.3 Prescribing error

The definition used in the present study was the widely accepted definition by (Dean et al., 2000):

''a *clinically meaningful prescribing error occurs when, as a result of a prescribing decision or prescription* [*ordering] process, there is an unintentional significant (a) reduction in the probability of treatment being timely and effective or (b) increase in the risk of harm when compared with generally accepted practice*''

3.3.3.4 Episode of care

An episode of care was defined by Hornbrook and co-workers (1985):

"The services of a single provider or selected multiple providers or to a single hospital stay or multiple hospitalizations within a specified time period".

Patients in the study site were usually transferred from a ward to another ward at some point during their hospital stay. In some cases, patients may need to be transferred from a ward to intensive care when a patient is critically ill. Therefore, the definition was amended to "*the services of a single provider or selected multiple providers or to a single ward stay or multiple wards within a specified time period"*

3.3.4 The study design

The present study was conducted as a cross-sectional, retrospective, process based (Franklin et al., 2005) audit for all pharmacist interventions collected for a one-month period (01/01/2015 - 31/01/2015). The time period chosen for this study ensured that new medical graduates who usually commence their rotations in February and August every year, had at least five months in the hospital context and therefore had some experience with the electronic prescribing system.

At the study setting, pharmacists were responsible for checking inpatient medication orders at or soon after patient admission and when medications reconciliation is undertaken. Inpatient medication orders are entered by the prescribers onto the electronic prescribing system and checked by the ward pharmacist, which is known as "signing off of orders". Pharmacists ensure medication order clarity, eligibility, completeness, and clinical appropriateness. Discharge medication orders are checked and authorised by a clinical pharmacist before dispensing of medications. These activities were usually undertaken by the clinical pharmacists on weekday basis. During the week days, clinical pharmacists routinely visited the wards systemically reviewing and analysing aspects of electronic medication orders as part of their normal duties. The average duration of their visit ranged from 2 to 3 hours daily. Not all wards are visited on a daily basis, although some specialities are. For example, areas such as critical care have a high pharmacist input with a minimum of daily visits, whereas a general surgical ward might have days without pharmacist visits.

According to the protocol deployed in the hospital, any order with a discrepancy, that was unclear, or had an error, would be intercepted by pharmacists and the prescriber would be

contacted to resolve any issues. Pharmacists' intervention was mainly based on their personal knowledge, clinical skills, and judgment. Also, they checked the medication history from different resources such as previous admission(s) or from general practice surgeries. When prescribing errors or drug omissions were found, an intervention would be made within the PICS system. An intervention would be made for example, in situations where an unsafe drug was identified owing to incorrect dose, frequency, route of administration, drug interaction, therapy duplication, treatment duration or medication omissions. Pharmacists recorded their interventions to the errors identified and classified them according to the severity of error in medication order scale created by Overhage and Lukes (1999). The text entry to the system associated with interventions contained various information such as the reason for the intervention, clinical significance, medication involved, ward involved with intervention, and date and time of intervention.

The severity of prescribing errors are assessed and categorised by clinical pharmacists into: potential fatal, serious, significant, and minor (Table 3.1). The interventions were entered and stored into the hospital electronic prescribing system interventions database. These interventions were displayed as messages linked to the prescriber who made the medication orders. During regular meetings with mentors, junior pharmacists had their interventions reviewed and the quality of their recording discussed. This was meant to ensure that pharmacists were consistent in their reporting of interventions. The process was inductive and developed and refined as information was gained.

Table 3.1. Severity of error in medication order (adapted from (Overhage and Lukes, 1999)).

Severity of error in medication order: Assess the inappropriateness of the order or its deviation from the standard of practice.
A. Potentially lethal • High potential for life-threatening adverse reactions. • Potentially lifesaving drug at a dosage too low for the disease being treated. • High dosage (>10 times normal) of drug with low therapeutic index.
B. Serious • Route of administration could lead to severe toxicity. • Low dosage of drug for serious disease in patient with acute distress. • High dosage (4–10 times normal) of drug with low therapeutic index. • Dosage resulted in serum drug concentration in potentially toxic range. • Drug could exacerbate the patient's condition (related to warnings or contraindications). • Misspelling or mix-up in medication order could lead to dispensing of wrong drug • Documented allergy to drug. • High dosage (10 times normal) of drug without low therapeutic index. • Omission of pretest for drug hypersensitivity.
C. Significant • High dosage (1.5–4 times normal) of drug with low therapeutic index. • Drug dosage too low for patient's condition. • High dosage (1.5–10 times normal) of drug without low therapeutic index. • Errant dual-drug therapy for single condition. • Inappropriate dosage interval. • Omission from medication order.
D. Minor • Incomplete information in medication order. • Unavailable or inappropriate dosage form. • Non-formulary drug. • Noncompliance with standard formulations and hospital policies. • Illegible, ambiguous, or nonstandard abbreviation.
E. No error • Information or clarification requested by physician or other health care professional from pharmacist. • Cost savings only.

3.3.5 Data extraction

All data related to inpatient medication order errors that were made by pharmacists, were retrieved from PICS and tabulated in Excel sheet form. The data included patients' descriptive data (date of admission, date of ward admission, date of ward discharge, and discharge date), ward associated with the intervention, date and time of intervention(s), and intervention(s) description.

The data were extracted from the system by the study facilitator at the Trust. Confidentiality was maintained by removing patients' personal data along with any data that referred to the prescribers that were involved in the errors. All data gained from the Trust were kept strictly confidential. The data were stored on a password-protected, computer, stored securely.

3.3.6 Interventions validation to assess the incidence and nature of prescribing errors

The analysis of the interventions was conducted by the principal investigator (FA). In the vast majority of cases, the pharmacist interventions provided sufficient information to facilitate a clear judgment regarding errors. When there were ambiguous interventions, the principal investigator contacted the study site facilitator to provide further clarification. The interventions were reviewed and consensus was reached on:

Whether the intervention is a prescribing error:

- Type of prescribing error according to the modified version of the EQUIP study to suit electronic prescribing (Dornan et al., 2009) (Table 3.2).
- Medication and medication class involved in the error according to the British National Formulary (BNF).
- Hospitalisation stage when the errors occurred. The stage of the patient's hospital stay was classified as "on admission", "during stay", or "on discharge".
- The ward involved in the error.

During the study, as a result of the discussions of the error with the supervision team, the principal investigator developed a more detailed list of "criteria", describing what should, and should not, be included as an error. The following criteria were established:

- The interventions should have one error type recorded per medication order.
- To avoid duplication of errors reported, for the interventions involving drug interaction prescribing errors, reports were assigned to the second of the two drugs prescribed.
- Interventions involving medication orders failing to follow the trust guidelines, were considered as an error. For example, failing to include diagnosis when ordering an antibiotic.

Table 3.2. Types of prescribing errors (adapted and modified from EQUIP study (Dornan et al., 2009).

1. Dosing Errors	- Overdosing - Under dosing - Dose rate errors - Strength error - Daily dose divided incorrectly - A dose not altered based on renal or hepatic lab results
2. Duplication	- Identical order - Same medication (but different dose, form, frequency, or route) - Different medication of the same therapeutic class
3. Data entry errors	- Unit errors (eg. mg instead of mcg) - Frequency errors - Route errors - Wrong drug (e.g. choosing error) - Incorrect formulation - Duration error - Timing error - Quantity error - Administration instructions missing or incorrect
4. Allergy status missing/significant allergy	- A drug is contraindicated because of a previous allergy
5. Drug Interactions	- A dug causes interaction with another drug when both are administered together
6. Omission of medication	- Unintentional omission of a medication
7. Inappropriate prescribing	- Unintentional prescription of drugs - Prescribing of medication under a name of wrong patient - Ineffective medication - Continuation of a drug for longer than needed - Prescribing a medication without taking the status of patient into account (e.g. prescribing a tablet form for patient cannot swallow) - Prescribing without following the hospital treatment guidelines.
8. Clinical errors	- Clinical contraindication not considered (e.g. prescribing combined hormonal contraceptive in a patient with two or more risk factors for thromboembolism) - Continuation of a drug after adverse drug reaction
9. Miscellaneous	- No dose indicated - Start date is incorrect - Premature discontinuation - Incomplete prescription - Lack of clarity - Non formulary item - No indication - Not classified

3.3.7 Inclusion and exclusion

All inpatient medication orders entered by prescribers between 01 January 2015 and 31 January 2015 were included in the study. Medication orders for ambulatory care and day care were excluded.

3.3.8 Data Statistical Analysis

The data were analysed by Statistical Package for the Social Sciences (SPSS) version 24 for Windows (SPSS Inc., Chicago, IL). Descriptive data analysis were used for characterising interventions to have an overall picture of the incidence of erroneous medication orders for each ward, severity category, BNF category and hospitalisation stage. The denominator used for calculating the error rate was the total number of medication orders. The overall prescribing error rate was calculated as the total number of errors divided by the total number of medication orders. The proportion of patients who were exposed to a potential prescribing error was calculated by dividing the number of prescribing errors detected by the number of patients admitted to the hospital over the period of the study.

The error rates for different wards were calculated by dividing number of errors identified in each ward by the total number of medication orders of each ward with 95% confidence intervals (CI). The associations between the incidence of erroneous medication orders with the type of ward were assessed using the Chi-squared (χ^2) test. In this study, $p < 0.05$ was considered statistically significant. $\chi 2$ tests were used to test the null hypotheses that associations between the incidence of erroneous medication orders with the type of ward.

3.3.9 Ethical Approval

Ethical approval was gained from the University of Birmingham (reference number ERN_15-0161). This retrospective data analysis did not require ethical approval as it was considered as an audit. The extracted data excluded any personal information or confidential patient data.

3.4 Results

During the study period, 131,947 medication orders were entered to PICS by medical and non-medical prescribers for 3981 patients. The mean number of medication orders entered during the study period for each patient was 33.1 medication orders per patient.

3.4.1 Pharmacists' interventions and prescribing errors

A total of 1629 interventions were documented by hospital pharmacists. These interventions combine both interventions not associated with prescribing errors and prescribing errors intercepted by pharmacists. There were 1481 prescribing errors intercepted before they reached patients. Prescribing errors accounted for 91% (1481/1629) of the total number of interventions. The remaining 148 interventions were excluded during review by the study investigator. The reasons for exclusions were monitoring errors, dispensing errors or messages to the prescribers. The relationship between pharmacist intervention and prescribing errors are shown in figure 3.1. The total of 1481 prescribing errors were found in 131947 medication orders giving an overall prescribing error rate of 1.1% (95% CI 1.1 to 1.2%). The proportion of patients exposed to a potential prescribing error was 37.2%.

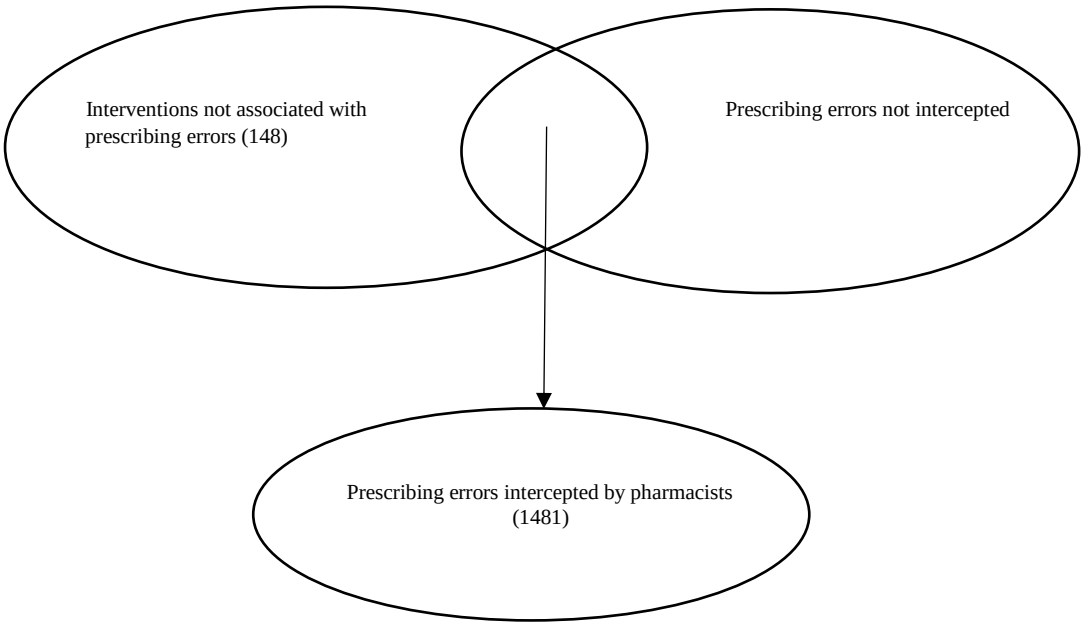


Figure 3.1. The relation between pharmacists' intervention and prescribing errors.

3.4.2 Types of prescribing errors detected

Omission of medication was most frequently observed prescribing error, occurring almost three times as frequently as the next most numerous type of error, accounting for 42.7% of all prescribing error types. Dosing errors were the next common type of errors accounting for (18.2%) and data entry errors accounting for (15.7%) of all errors recorded as shown in table 3.3.

Table 3.3.Type of prescribing errors.

Type of error	n	%
Omission of medication	632	42.7
Dosing errors	270	18.2
Data entry error	233	15.7
Miscellaneous	160	10.8
Inappropriate prescribing	109	7.4
Clinical error	32	2.2
Drug interaction	21	1.4
Duplication	16	1.1
Allergy error	8	0.5
Total	1481	100

3.4.3 Prescribing errors according to hospitalisation stage

Table 3.4 demonstrates prescribing errors expressed by the stage of hospital stay. Most of errors associated with medication orders occurred at the time of hospital admission (56.5%). These were twice as high when compared to the errors associated with medication orders during hospital stay (28.7%). The error rate associated with discharge medication orders was 14.8%.

Table 3.4: Prescribing errors according to hospitalisation stage

Hospitalisation stage	n	%
On admission	837	56.5
During stay	425	28.7
On discharge	219	14.8
Total	1481	100

On discharge, 6987 medication orders were entered by prescriber through the system (Table 3.5). Erroneous medication orders were found in 3.1% of the total medication orders (219/6987). The highest error rates were observed in medication orders entered in the critical

care 12.5%, vascular surgery 9.4% and urology 9.3% specialities. However, in the critical care speciality only one error in 8 medication orders was actually found. No error was found in the 217 medication orders in cardiology discharge prescriptions. According to the discharge policy at the study site, medications are not re-dispensed if there are no changes on repeat prescriptions and the patient has sufficient at home.

Table 3.5. Erroneous medication orders in discharge mediation orders.

Ward	Number of errors	Number of orders	%
Critical Care	1	8	12.5
Vascular Surgery	10	106	9.4
Urology	28	301	9.3
General Medicine	94	1777	5.3
Trauma & Orthopaedics	8	193	4.1
Neurosciences	13	315	4.1
Clinical Haematology	5	195	2.6
Liver	11	493	2.2
Renal	8	388	2.1
Plastic Surgery	1	55	1.8
General Surgery	14	805	1.7
Cardiothoracic Surgery	5	299	1.7
Ear, nose & throat	5	291	1.7
Maxillofacial Surgery	2	150	1.3
Oncology	14	1394	1
Cardiology	0	217	0
Total	219	6987	3.1

3.4.4 Prescribing error frequency by medical speciality

There was a wide level of variability in the error rates observed in wards used by different specialities (Table 3.6). The largest specialties ward associated with erroneous medication orders were reported in general medicine (61.5%), followed by urology (9.7%), oncology (5.7%) and general surgery ward (5.1%). The wards that had the least occurrence of errors were maxillofacial surgery and cardiology 0.6% and 0.1% respectively.

Table 3.6.Prescribing errors by medical speciality.

Ward	n	%
General Medicine	911	61.5
Urology	144	9.7
Oncology	84	5.7
General Surgery	75	5.1
Neurosciences	36	2.4
Renal	36	2.4
Liver	35	2.4
Trauma & Orthopaedics	34	2.3
Vascular Surgery	24	1.6
Clinical Haematology	23	1.6
Ear, Nose & Throat	22	1.5
Cardiothoracic Surgery	19	1.3
Critical care	14	0.9
Plastic Surgery	13	0.9
Maxillofacial Surgery	9	0.6
Cardiology	2	0.1
Total	1481	100

3.4.5 Medications involved with prescribing errors

Table 3.7 classifies the medication orders associated with prescribing errors according to the BNF therapeutic categories in descending order. The most common errors associated with medication orders according to the BNF categories were with cardiovascular (20.5%), infection (15.7%), central nervous system (14.5%) and respiratory system medications (11.5%). Through examination of the BNF sub therapeutic categories showed that antibiotics had the greatest rate of erroneous medication orders (211, 14.2%), followed by single and combined inhaled bronchodilator agents (81, 5.5%) and diuretics (71, 4.8%). Data were missing in 20 interventions where the medications associated prescribing errors could not be identified.

Table 3.7. Medication classes according to BNF categories.

BNF Category	n	%
Cardiovascular system	303	20.5
Infections	233	15.7
Central nervous system	215	14.5
Respiratory system	170	11.5
Nutrition and blood	132	8.9
Endocrine system	118	8.0
Gastro-intestinal system	115	7.8
Eye	62	4.2
Obstetrics, gynaecology, and urinary-tract disorders	33	2.2
Musculoskeletal and joint diseases	30	2
Malignant disease and immunosuppression	19	1.3
Skin	15	1.0
Ear, nose, and oropharynx	12	0.8
Anaesthesia	4	0.3
Total	1461	98.6
Missing	20	1.4
Total	1481	100

3.4.6 Severity of erroneous medication orders

The majority of errors associated with erroneous medication orders were deemed potentially significant (68.5%) or minor (26.3%). Potentially serious errors were much less common (5.1%) and potentially lethal errors were found in only 0.1% of erroneous medication orders (Table 3.8).

Table 3.8. Severity of erroneous medication orders.

Error category	n	%
Minor	389	26.3
Significant	1014	68.5
Serious	76	5.1
Potentially lethal	2	0.1
Total	1481	100

3.4.7 Incidence of prescribing errors by ward speciality

Differences in error rates were observed in individual ward specialities. Also, the total number of medication orders varied at each ward speciality (Table 3.9). These ranged from 1851 medication orders in vascular surgery to 34735 medication orders at general medicine.
The urology ward had the highest rate of errors associated with medication orders 3.6% (CI 3.1 – 4.2), followed by general medicine 2.6% (CI 2.5 – 2.8). The lowest error rates was observed in cardiology with an error rate 0.1% (CI 0 – 0.2).

Table 3.9. Errors distribution according to ward speciality.

Wards	Description	Total
General Medicine	Errors (n) Errors [% (95% CI)] Total Number of orders: 34735	911 2.6 (2.5 – 2.8)
Urology	Errors (n) Errors [% (95% CI)] Total Number of orders: 4013	144 3.6 (3.1 – 4.2)
Oncology	Errors (n) Errors [% (95% CI)] Total Number of orders: 17520	84 0.5 (0.4 – 0.6)
General Surgery	Errors (n) Errors [% (95% CI)] Total Number of orders: 12967	75 0.6 (0.5 – 0.7)
Neurosciences	Errors (n) Errors [% (95% CI)] Total Number of orders: 5590	36 0.6 (0.5 – 0.9)
Renal	Errors (n) Errors [% (95% CI)] Total Number of orders: 7013	36 0.5 (0.4 – 0.7)
Liver	Errors (n) Errors [% (95% CI)] Total Number of orders: 6270	35 0.6 (0.4 – 0.8)
Trauma & Orthopaedics	Errors (n) Errors [% (95% CI)] Total Number of orders: 4142	34 0.8 (0.6 – 1.1)
Vascular Surgery	Errors (n) Errors [% (95% CI)] Total Number of orders: 1851	24 1.3 (0.9 – 1.9)
Clinical Haematology	Errors (n) Errors [% (95% CI)] Total Number of orders: 4136	23 0.6 (0.4 – 0.8)
Ear, Nose & Throat	Errors (n) Errors [% (95% CI)] Total Number of orders: 4216	22 0.5 (0.3 – 0.8)
Cardiothoracic Surgery	Errors (n) Errors [% (95% CI)] Total Number of orders: 4557	19 0.3 (0.4 – 0.7)
Critical Care	Errors (n) Errors [% (95% CI)] Total Number of orders: 14891	14 0.1 (0.1 – 0.2)
Plastic Surgery	Errors (n) Errors [% (95% CI)] Total Number of orders: 4202	13 0.3 (0.2 – 0.5)
Maxillofacial surgery	Errors (n) Errors [% (95% CI)] Total Number of orders: 2230	9 0.4 (0.2 – 0.8)
Cardiology	Errors (n) Errors [% (95% CI)] Total Number of orders: 3714	2 0.1 (0 – 0.2)
Total	Errors (n) Errors [% (95% CI)] Total Number of orders: 131947	1481 1.1 (1.1 – 1.2)

3.4.8 Prescribing errors per ward care episode

Table 3.10 shows the frequency of errors that were intercepted in different ward care episodes. The frequency of errors varied between the different wards specialities. Wards had differing levels of activity, as measured by care episodes. The nature of the ward in terms of speciality, case-load and case-mix could have indirect influence on the activities that have been carried out within that environment and hence prescribing activities would be affected. The highest rates of error per ward care episode were found in general medicine ward 0.77 per care episode. The cardiology ward had the lowest rate 0.004 error per episode (2 errors in 458 hospital care episode). The overall errors per ward care episode was 0.1.

Table 3.10. Prescribing errors distribution per care episode.

Ward	Number of errors	Number of care episode	Error per ward care episode
General Medicine	911	1179	0.77
General Surgery	75	2376	0.03
Trauma & Orthopaedics	34	1266	0.02
Liver	35	664	0.05
Renal	36	2118	0.01
Cardiology	2	458	0.004
Cardiothoracic Surgery	19	236	0.08
Neurosciences	36	598	0.06
Ear, nose & throat	22	404	0.05
Vascular Surgery	24	192	0.12
Oncology	84	2931	0.02
Urology	144	558	0.25
Clinical Haematology	23	416	0.05
Critical Care	14	456	0.03
Plastic Surgery	13	306	0.04
Maxillofacial Surgery	9	199	0.04
Total	1481	14357	0.1

3.4.9 Severity of errors identified across ward specialities

Table 3.11 shows the severity of the errors identified in different wards specialities. The majority of errors were categorised as significant amounting to 68.5% (1014/1481) of the total, followed by minor errors which accounted for 26.3% (389/1481). Errors categorised as potentially lethal accounted for 0.14% (2/1481). A more detailed analysis of the severity of the errors at each ward showed that the majority of errors were reported in general medicine with a severity rating of 17.4% minor, 41.4% significant, 2.6% serious and 0.14% potential lethal. During the study period, only two potential lethal errors were reported in the general medicine ward. The cardiology ward had only 0.14% (2 errors) which were categorised as minor errors.

Table 3.11. The severity of errors observed in different ward specialities.

Ward	Minor	Significant	Serious	Potentially Lethal	Total
General Medicine	257	613	39	2	911
Urology	21	116	7	0	144
Oncology	32	48	4	0	84
General Surgery	18	55	2	0	75
Neurosciences	6	28	2	0	36
Renal	10	24	2	0	36
Liver	5	22	8	0	35
Trauma & Orthopaedics	6	26	2	0	34
Vascular Surgery	13	9	2	0	24
Clinical Haematology	6	14	3	0	23
Ear, Nose & Throat	4	16	2	0	22
Cardiothoracic Surgery	2	14	3	0	19
Critical care	3	11	0	0	14
Plastic Surgery	1	12	0	0	13
Maxillofacial Surgery	3	6	0	0	9
Cardiology	2	0	0	0	2
Total	389	1014	76	2	1481

3.4.10 The types of error and the wards summary

The incidence and types of error detected in each ward location are summarised in table 3.12. The most frequent error types for all wards specialities were omission of medication,

accounting for 42.7%, dosing errors accounting for (18.2%) and data entry errors accounting for (15.7%) of all errors recorded. The error type observed least frequently were allergy errors where only 8 errors (0.5%) were observed during study period, of those 6 were detected in general medicine wards.

There was large difference in the variability of error types across different wards specialities which ranged from 61.5% to 0.1% across the wards. General medicine ward had the highest proportion of errors compared the other wards.

Table 3.12. The types of errors and the wards summary.

Wards	Error type									Total	%
	Allergy error	Clinical error	Data entry error	Dosing error	Drug interaction	Duplication	Inappropriate prescribing	Miscellaneous	Omission of medication		
General Medicine	6	23	140	155	11	8	69	118	381	911	61.5
Urology	0	1	16	20	4	2	9	7	85	144	9.7
Oncology	0	1	15	14	0	1	12	8	33	84	5.7
General Surgery	0	3	10	15	1	2	7	16	21	75	5.1
Neurosciences	2	0	6	10	0	0	1	0	17	36	2.4
Renal	0	0	2	13	0	1	3	2	15	36	2.4
Liver	0	2	5	13	0	0	2	1	12	35	2.4
Trauma & Orthopaedics	0	1	3	9	0	1	0	2	18	34	2.3
Vascular Surgery	0	0	7	3	0	0	0	2	12	24	1.6
Clinical Haematology	0	1	10	4	0	0	0	1	7	23	1.6
Ear, Nose & Throat	0	0	5	1	2	0	0	1	13	22	1.5
Cardiothoracic Surgery	0	0	8	3	1	1	1	0	5	19	1.3
Critical Care	0	0	0	4	2	0	4	0	4	14	0.9
Plastic Surgery	0	0	4	3	0	0	0	0	6	13	0.9
Maxillofacial Surgery	0	0	1	2	0	0	1	2	3	9	0.6
Cardiology	0	0	1	1	0	0	0	0	0	2	0.1
Total	8	32	233	270	21	16	109	160	632	1481	100
%	0.5	2.2	15.7	18.2	1.4	1.1	7.4	10.8	42.7	100	

3.4.11 Types of prescribing error and their severity

Table 3.13 demonstrates the severity of errors along with their types. The severity of the errors observed during the study period appeared to vary according to the error types. More than half of the errors observed were due to omission of medications, dosing errors, and data entry errors (Table 14). The most common type of prescribing error was omission of medication accounting for 42.7% of the total: of these 78% (493) and 4.1% (26) were categorised as significant and serious receptively. Dosing errors accounted for 18.2% of the total with 79% of these categorised as significant. Data entry errors were observed in 15.7% of erroneous medication orders. Only two cases of potentially lethal errors that were due to duplication and dosing errors. Examples of type of errors observed with their severity rating are shown in Table 3.14.

Table 3.13. Severity of prescribing errors cross-tabulated with their types.

Type of prescribing errors	inor	Significant	Serious	Potentially lethal	Total
Omission of medication	113	493	26	0	632
Dosing error	36	213	20	1	270
Data entry error	83	137	13	0	233
Miscellaneous	133	27	0	0	160
Inappropriate prescribing	16	87	6	0	109
Clinical error	4	24	4	0	32
Drug interaction	0	17	4	0	21
Duplication	0	15	0	1	16
Allergy error	4	1	3	0	8
Total	389	1014	76	2	1481
%	26.3	68.5	5.1	0.1	100

Table 3.14. Examples of prescribing errors detected.

Severity category	Type of prescribing errors	Intervention
Minor	Data entry error (route error)	Co-trimoxazole route changed from IV to oral on TTO
Significant	Drug interaction	Simvastatin prescribed concurrently with cyclosporine
Serious	Dosing error	1 gram vancomycin prescribed and patient GFR only 37ml/min.
Potential lethal	Dosing error	The dose of cytarabine is too high for age of patient. Dose needs to be 50% reduced.

3.4.12 Severity of prescribing errors with the hospitalisation stage

More than 60.1% (614/1014) of prescribing errors were categorised as a significant errors occurring at the admission stage (Table 3.15): the highest rates of error for all error types were observed during this stage of hospitalisation with the exception of two errors classified as potentially lethal that occurred in the "during stay" stage.

Table 3.15. Severity of prescribing errors cross-tabulated with hospitalisation stage.

Stage	Error category				Total
	Minor	Significant	Serious	Potentially lethal	
On admission	191	614	32	0	837
During stay	150	244	29	2	425
On discharge	48	156	15	0	219
Total	389	1014	76	2	1481

3.4.13 Incidence of prescribing errors by ward speciality

The incidence of erroneous medication order, irrespective of their severity, was significantly greater in the general medicine ward (911/122967(2.6%)), compared with general surgery ward (75/12967 (0.6%) ($\chi 2 = 194.9$, df=1, $p<0.001$). A further analysis of specialised wards, showed significantly higher error rates on specialised surgical wards (urology, neurosciences, trauma & orthopaedics, vascular surgery, ENT, cardiothoracic surgery, plastic surgery, and maxillofacial surgery) (301/30801(0.98%)), when compared to specialised medical wards (oncology, renal, liver, clinical haematology, and cardiology) (178/38653 (0.46%)) (($\chi 2 = 66.8$, df=1, $p<0.001$).

3.5 Discussion

3.5.1 Findings:

The present study examined the identification of electronic prescribing errors detected and reported within pharmacists' interventions during daily routine activities validating medication orders in an inpatient English hospital. Prescribing errors were identified in 1.1% of medication orders and were associated with a wide variety of prescribing error types. Hospital pharmacists identified and rectified these errors before they reached patients. The majority of prescribing errors reported were minor and significant (26% and 68.5% respectively), with only 5.2 % classified as serious or potentially lethal.

The results indicated that that most of the errors occurred at admission; which can be explained by the significant level of prescribing activities occurring on admission, along with the known drug history issues that can arise during admission. There were significant differences in error rates between ward specialities, which could be due to training in prescribing variations and different focus of the prescribers as well as differences in prescribing activity between them. In the current study, high prescribing errors rates were observed in wards with high absolute number of prescribing activities.

The overall prescribing error rate (1.1%) in this study was low compared to the rates reported in a number of previous studies (Colpaert et al., 2006, Shulman et al., 2005). This result indicates that the system operated in the study site seems to be efficient for reducing the risk of prescribing errors.

The reported error rate in this study was similar to a previous reported study error rate 2% (Donyai et al., 2008) which used similar methods. However, in the present study, data were taken from different ward specialties which make it difficult to compare it with other studies owing to differences in the study designs, settings, and prescribing errors definition used (Franklin et al., 2005, Lewis et al., 2009). The current study was conducted in a teaching hospital; hence it is unknown how this will likely to have affected the results. However, the time period chosen for this study was before junior medical staff commence their rotations. Obviously there is likely to be a difference between teaching and non-teaching settings and between hospitals using different types of sophistication levels of electronic prescribing

systems. The present study did not look for error rates between different grades of prescribers or differences between medical and non-medical prescribers.

In the present study, the proportion of patients exposed to a potential prescribing error was 37.2%, which was slightly lower than a previous published study which found prescribing errors in 41.3% of patient prescription charts in teaching hospitals (Ryan et al., 2014). The proportion of prescriptions with errors was similar, and variation in the incidence of prescribing errors between could be related to the error detection method used or differences in error rate.

Unintended omission of medication at the admission stage was most frequent error encountered compared to the other types of prescribing errors. This result is in agreement with previous studies (Dornan et al., 2009, Franklin et al., 2011). This can be explained owing to the lack of full medication history of patients upon admission which might be unavoidable sometimes. Therefore, conducting medication reconciliation upon admission could be beneficial to reduce unintended medication discrepancies and prescribing errors. Previous research has shown that conducting medication reconciliation at the admission stage can reduce the omission of medications (Mazhar et al., 2017, Mills and McGuffie, 2010, Richards et al., 2011). Considering the risk of unintended omission of medications on admission, thereby, expanding the role of pharmacists in interdisciplinary teams during patient clerking could be valuable in conducting a structured medication reconciliation. This would help minimise the occurrence of unintended omissions. Pharmacists have the ability to obtain complete and accurate medication histories as well as performing medication reconciliation (Gleason et al., 2004, Gleason et al., 2010, Pippins et al., 2008). Therefore, changing the current daily practice of pharmacists to be involved on admission stage would ensure sustainable change for the patients' safety.

Most of the omission errors noted in this study would have been corrected during admission or prior to discharge, through the pharmacist clinical check. This emphasises the importance of medicines reconciliation at hospital admission, in order to reduce the possibility of missed doses of essential medicines. In the UK, according to the patient safety guidance issued by the National Institute for Health and Care Excellence (NICE) and National Patient Safety Agency (NPSA) recommended that medicines reconciliation should be undertaken within 24 hours of admission and pharmacists should be involved (NICE, 2007). However, the lack of time and availability of pharmacists, particularly out-of-hours during patient admissions, may be an issue. The expanding and novel role of pharmacists in acute settings may be of particular

benefit (Hughes et al., 2017). Involving pharmacists would benefit not only medicines reconciliation but also medicines review.

Prescribing errors that occurred at the admission phase could be attributed to the lack of access to summary care records in secondary care settings. This can be identified as a major threat to patient safety. In a qualitative study investigating the causes of prescribing errors among hospitalised patients, lack of an accurate medication history upon admission was identified as the main cause of prescribing error (Ross et al., 2013). Currently, summary care records which provide data about medications, allergies and adverse reactions are available for over 96% of England population (National Health Services, 2016). However, discrepancies may occur between summary care records and current medications being used by patients during transferring of care between primary and secondary care. A study carried out by Drenth-van Maanen and co-workers (2011), found that medication records had discrepancies in 92% of patients in a US academic hospital and 72% of these discrepancies were judged as potentially clinically relevant. In the UK, Garfield and colleagues found medication discrepancies affected 70% of medication prescribed on admission for around 60% of patients on admission to hospital (Garfield et al., 2009). Therefore, the current drive for a strategic plan to build a national electronic health care records nationally holds promise to counteract this issue. This approach would ensure accurate transfer of medication information between different health care settings (primary and secondary care) at the interface of care. This would help to minimise human errors and reduce medication discrepancies which would consequently be expected to lead to improvements in patient care.

Interestingly, it was revealed that the main drug classes involved in pharmacists' interventions, according to BNF therapeutic categories, were medications for the cardiovascular system, antibiotics, and central nervous system, which were similar to previous study findings (Bedouch et al., 2008, Ferracini et al., 2018, Kuo et al., 2013). This probably reflects that these classes of medication are amongst the most common drugs prescribed in general medicine, general surgery and critical care wards which constituted the majority of the prescribing, where patients may have more complex conditions compared to other specialities. Therefore, these medication classes are good targets for future interventions such as improving the current electronic prescribing system or conducting an education intervention.

Moreover, the present study mirrors the finding that dosing errors are common even when using an electronic prescribing system. This finding is in line with previous research (Bedouch et al., 2008, Lustig, 2000, Seden et al., 2013). The electronic prescribing system (PICS) has the default doses for the drugs that have variable dosage forms. Prescribers often are time pressured and errors occur when they forget to change the default doses or when using drop down menu they make an incorrect selection.

The current study highlighted the errors specifically associated with an electronic prescribing system. These are termed "Data entry errors" which include frequency, route, or unit errors and accounted for 15.7% of the total errors observed. Such errors could arise when prescribers use the system with the absence of programmed safeguards that can help to prevent erroneous medication orders. For example, the way the system automatically defaults required fields (route, frequency or timing) erroneously when a medication is selected. Kushniruk and co-workers, examined how technololgy, in terms of an electronic prescribing system, can introduce prescribing errors (Kushniruk et al., 2005). They found certain data entry errors can result from an automated default feature such as dosing or route that the electronic prescribing system has as well as issues related to the user interface such as data display on the screen.

In previous research, Campbell and colleagues (2006) found that electronic prescribing system designs such as poor data presented on the screen and lack of understanding from the users about the system functionality will contribute to the new type of errors. These errors include picking up errors or "juxtapositions errors" when a prescriber selects an incorrect choice without realising it (Campbell et al., 2006). Therefore, it is necessary for the prescribers to have a robust knowledge about how the system works as well as adequate training which will enable them to prescribe safely. Also, system configuration could be optimised to prevent such errors. This configuration could include a dosing decision support feature which is linked patient's laboratory results. For example, the system could give the prescriber a suggested drug dose based on the laboratory clinical data of the patient. Moreover, prescribers need to be vigilant during prescribing on an electronic prescribing system and try to apply a systematic approach similar to that applied during the diagnosis process.

More than half of the errors observed in the current study were significant, with potential of aggravating the patient's condition owing to omission of medications, dosing errors, data entry errors, drug interactions and duplicate-drug therapy for a single condition; these results are in line with those found by Abdel-Qader et al. (2010) (76.3% of cases) and Dornan et al. (2009)

(52.8% of cases). In the current study, only two cases of potentially lethal errors were detected. The severity of errors reported in the present study were closely similar to the rating in a previous study (Donyai et al., 2008).

The finding from the present study revealed that there were a significantly higher error rates on the general medicine ward compared to the general surgery ward. These findings are in agreement with a previous study (Seden et al., 2013) which showed similar patterns. The possible explanation of this finding is that surgical staff usually do not initiate treatment out of their therapeutic area. However, in general medical wards drug treatment regimens are often more complex compared to those in surgical areas. When focusing on specialised wards, in surgical specialities wards prescribing error rates were higher than in specialised medical wards. These findings are similar to the previous studies (Klüchtzner and Grandt, 2015, Ryan et al., 2014). This could be as a result of the fact that surgical hospitalisations are mainly focused on acute interventions rather that current therapeutic management of co-morbidities of patients, which is an error-prone factor especially in polypharmacy patients. Consequently, this shows the importance of inter-professional coordination between different surgical and medical teams for patient medication management in particular for polypharmacy patients.

It is difficult to conduct a study that determines the incidence of prescribing errors per patient as the hospital in the present study and wards have high turnover of patients. In the present study setting, patients could be counted more than once as they are transferred between wards. For example, a patient may be admitted to a medical or surgical ward for assessment and investigations, and then later be transferred to an intensive care units or other specialist ward. Patients can also transferred from a speciality to another; for example from a medical specialised medical to a surgical specialised wards. There is currently no way to control for the problem of multiple patient episodes, when trying to calculate incidence rate.

3.5.2 Implications for the hospital practices

The present study contributes to the body of literature indicating that hospital pharmacists are able to identify suboptimal prescribing practices and intervene accordingly. The current study demonstrates the role and importance of pharmacists in clinical monitoring functions for patients utilising an electronic intervention supported by an electronic prescribing system. This allows pharmacists to screen medication orders, intervene to deal with errors and follow up

queries with prescribers. However, this screening is currently limited owing to the pharmacy service provision model. Patients who arrive at night will not be screened until the next day, and those arriving during the weekend will not be seen until the following Monday. A more systematic approach, with greater service provision during these times would provide a "safety net" to prevent patient harm during hospitalisation. Such an approach would require clinical pharmacists to be involved at the stage of admission and also within clinical decision units.

This was supported by Mills and McGuffie (2010) who investigated the role of clinical pharmacists to reduce prescribing errors by improving the accuracy of any medication history upon unplanned admissions in emergency department. They found a significant reduction in prescribing error rate from 3.3 errors to 0.04 errors per patient (difference 95% CI 2.5 to 5.1), following medication reconciliation that was carried out by the pharmacists (Mills and McGuffie, 2010). Pharmacists will ensure an accurate medication history to be taken from patients (Fertleman et al., 2005), review and record a medication list in the hospital electronic system, and discuss with the clinical team the appropriateness for current medications throughout the admission. Such models can transform the pharmacy profession from traditional supply role to clinical services role. Previous research has shown that up to 97% of clinical pharmacist recommendation interventions were accepted by the prescribers (Delpeuch et al., 2015, Ferracini et al., 2018, Kuo et al., 2013, Yeoh et al., 2013). These interventions include drug changes, inappropriate prescribing and drug dosing adjustments. The present study did not measure the acceptance rate by prescribers as it was beyond the scope of this research.

In the present study, pharmacists keep track of current medications from the patients and/or their general practitioner and document all information, double check that their electronic drug chart reflected this 'medication history', discuss any discrepancies with the medical team and ensure errors were corrected. These activities are similar to medicines reconciliation as defined by the National Prescribing Centre in the UK "*collection of information on medication history, checking this list against the current drug chart in the hospital and communicating changes, omissions and discrepancies*" National Prescribing Centre (2007), and as used in the USA *"a sequence of events involving verification of use, identification of discrepancy and rectification of errors"* (Vira et al., 2006). The Institute for Healthcare in the US, included medication reconciliation as a strategy to improve patient safety in their '5 Million Lives' campaign (Institute for Healthcare Improvement (2009). The implementation of this strategy is presently a National Patient Safety Goal of the Joint Commission on Accreditation of Health Care

Organizations (2018). The Healthcare Commission, which evaluates the performance of healthcare organisations in the UK, suggested that "shortfalls in transferring information" about medicines needs to be addressed (2007). The National Institute for Health and Clinical Excellence (NICE) has since made recommendations for good practice in this area (NICE, (2007).

The Erice Medication Errors Research Group recommendations for reducing prescribing errors, includes training and continuous assessment of prescribers skills, continuous monitoring of prescribing, improve awareness and communication (Agrawal et al., 2009). Involvement Clinical pharmacists at all stages of the medication use process is also recommended (Agrawal et al., 2009) which is vital to act as a safety net to patients from prescribing error (regardless of the use of electronic prescribing), and this includes the use of ward-based and dispensary pharmacists to perform routine checks on all generated prescriptions (Dean et al., 2002a, Dornan et al., 2009, Fernandez-Llamazares et al., 2012, Klopotowska et al., 2010). This possibly delivers the safety net against prescribing error, and has the best utility when applied in clinical areas liable to highest risk, for example patients with complex cases with multiple medication (polypharmacy), and hospital clinical decision units.

In the current study, prescribing errors are common in some wards. Many of them were categorised as clinically significant. Therefore, implementing full time ward-based clinical pharmacists will help to address prescribing errors identified, as well as providing recommendations for prescribers. This would consequently improve the outcome of patient care. Further research is needed to assess the impact of clinical pharmacist interventions on optimisation of prescribing.

3.5.3 Study limitations

There are several limitations associated with the present study. Firstly, the study was conducted in a single teaching hospital, which potentially reduces the general application of the findings to other clinical settings. Data were taken from ward based pharmacists' interventions and relied on individual pharmacists identifying, intervening errors, and documenting all problems correctly. Therefore, there might be variability between pharmacists in the numbers and nature of prescribing errors documented. The failure either to detect or to record errors would lead to

an underestimation of the actual prescribing error rate in hospital inpatients. A prospective study could develop clear criteria and explicit training to ensure pharmacist interventions were consistently applied. Any retrospective review of pharmacist interventions will always be dependent on the varied clinical experience and training of pharmacists, as well as personal subjective views on what types of prescribing errors required intervention.

Comparison of the results of the present study with previous studies may be affected by several factors such as variation in prescribing procedures, and individual prescribers' practice. More work will be required to test the generalised application of these findings to other specialties and other NHS organisations.

3.6 Conclusion

Prescribing errors still occur even when using electronic prescribing systems. Prescribing errors occur most frequently on admission compared to other stages during hospitalisation. The present study identifies an area that needs to be improved in the current method of transferring and sharing patients' data between primary and secondary care. Also, prescribers need to be vigilant when they prescribe using an electronic prescribing system. Pharmacists have a vital role in identifying and preventing prescribing errors before they might harm patients. Pharmacists' role within hospitals need to be expanded to include their integration within medical teams providing collaborative patient care.

4 Chapter Four: A Qualitative Exploration of Medical and Non-Medical Prescribers' Views and Concerns On Using an in-patient Electronic Prescribing system

4.1 Introduction

In 10% of all UK admissions, patients are harmed owing to adverse events with costs totalling £2billion annually owing to prolonged bed stays (Donaldson et al., 2000). Out of the 10% adverse events, medication errors are responsible for 10 to 20% of admissions, costing between £200-400 million annually (Smith and Cavell, 2004). In 2001, there were 1100 resultant patient deaths caused by medication errors or adverse drug reactions, as stated by the Audit Commission (Yeates, 2001). This does not reflect, but is suggestive of the additional in-patient days also resulting from errors in medication (Yeates, 2001). These data are significant and indicative of a greater issue. Patient safety initiatives are targeting prescribing errors, as they are responsible for a large proportion of all medication errors and the resultant injury to patients (Dean et al., 2002a). Elimination of errors during prescribing would have a major impact on the reduction of all errors in medication use processes.

It has been recognised by international organisations (Kohn et al., 2000, Smith and Cavell, 2004), that patient safety and improving standard of care, as well as medication errors are immediate health policy concerns. This has been illustrated in 'To Err is Human: Building a Safer Health System', reported by the Institute of Medicine in the United States of America (USA) (Kohn et al., 2000) which aims to educate the public on these concerns an in 'An Organisation with a Memory', which is a report that focused on adverse events occurring in the NHS (Donaldson et al., 2000). The latter report also recommended that the Department of Health should target urgent initiatives to reduce prescribing errors by 40% by 2005.

In the UK, prescribing errors are estimated to occur in 8.9 to 14.7% of inpatient and discharge medications (Dornan et al., 2009, Franklin et al., 2011, Seden et al., 2013). This is a matter of concern for all in the NHS, patients and staff alike. Health policy makers should target more initiatives to improve patient care, optimising prescribing to reduce these figures as a matter of high priority. The use of electronic prescribing systems has been suggested as a potential initiative to solve prescribing errors, thus improving efficiency and patient safety (Donaldson

et al., 2000, Kohn et al., 2000, Pricewaterhouse Coopers, 2013). An electronic Prescribing system has been defined as:

"the utilisation of electronic systems to facilitate and enhance the communication of a prescription or medicine 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, 2007).

It has been stated by the UK Health Foundation that using electronic prescribing systems, with integrated decision support functionality could reduce prescribing errors by 50% (The Health Foundation, 2012). This would be expected to improve the quality of patient care and safety. However, 'sociotechnical errors' are now occurring which is defined as '*errors occur at the point where the system and the professional intersected and would not have occurred in the absence of the system*' (Redwood et al., 2011).

Electronic prescribing systems are extensively found in primary care (Sheikh et al., 2011b), but have lagged behind in previous decades in secondary care (Cornford et al., 2009). However, in recent years there has been a rapid implantation of e-prescribing systems in the NHS with over a third of the NHS hospitals having prescribing systems (A Slee, personal communication, 01 May 2018). By 2020 it is expected all secondary care hospitals will have electronic prescribing systems (Department of Health, 2013). Initially the National Programme for IT (NPfIT), spearheaded by England's Connecting for Health was established in 2002 with the aim of creating a unilateral electronic care record for all patients. This would improve connectivity between hospitals and general practices. All health institutions had aimed to be connected by 2010, this was largely unsuccessful (House of Commons Public Accounts Committee, 2009, Public Accounts Committee, 2011). In September 2011, NPfIT was dismantled, and a move to a more local system where NHS trusts have more independence for IT procurement to meet local needs.

The use of electronic prescribing system (EPS) in addition to Clinical Decision Support (CDS) has been proved to reduce prescribing errors (Bates et al., 1998, Bates et al., 1999b, Garg et al., 2005, Kaushal et al., 2006, Nuckols et al., 2014). These systems allow prescribers to *"facilitate and enhance the communication of a prescription, aiding the choice, administration or supply of a medicine through decision support and provide a robust audit trail for the entire medicines use process"* (NHS Connecting for Health, 2007). Although evidence suggests EPSs (with or without CDS) reduce prescribing errors, new types of error have emerged associated

with them (Campbell et al., 2006, Gandhi et al., 2005, Koppel et al., 2005). For example, as a result of a wrong selection on a drop-down menu, a prescription for diamorphine was generated at 70 times the required dosage (Shulman et al., 2005). This, again, reflects the serious nature of prescription errors and has been reported as 'unintended adverse consequences' (Ash et al., 2007a, Campbell et al., 2006) of the system. The use of this particular phrase stresses the unanticipated and unwanted effects of the circumstances (Ash et al., 2007c).

Potential explanations for the delay in the implementation of electronic prescribing systems in secondary care are due to the unwanted issues once it is in place (Barber, 2010, Cresswell et al., 2014, Redwood et al., 2011, Schiff et al., 2015). These are numerous. Medical staff have reported that EPS have negative effects on their clinical workflows (Niazkhani et al., 2009) and reduces the opportunity for teamwork (Cresswell and Sheikh, 2015) and interactions within the medical team (Westbrook et al., 2013b). EPS has also been shown to redistribute time for patient care (Sheikh et al., 2011a) as there is more data entry required. Additionally, staff have to learn the new system and adapt their previous methods of working. This has resulted in the creation of 'workarounds' and the system is used in ways not intended for (Cresswell et al., 2017, Cresswell et al., 2012, Ferneley and Sobreperez, 2006).

Poorly designed and over-complicated systems may contribute to prescribing errors and unexpected new consequences to patient safety. The systems do not account for socio-techno-cultural issues and how these are a hindrance for users. Secondly, over-complicated approaches also increase errors and systems need to be more intuitive with a focus on user-centred design. Lastly, the systems fail to account for interactions between the user and the system, further emphasising errors (Sheikh et al., 2011b).

Poor interface design has shown to cause frustration and increase potential sources of errors (Cheng et al., 2003, Horsky et al., 2003). Poor electronic prescribing systems design has been found to be the cause of adverse drug events, rather than human error in some cases (Ash et al., 2007b, Koppel et al., 2005, Peute and Jaspers, 2007). The more taxing the system interface creates a heavy cognitive demand on the user leading to the increased likelihood of errors as well as poor utilisation of system features (Horsky et al., 2003, Horsky et al., 2004).

In previous studies focusing on Foundation Trainees and junior doctors, a multitude of causes were found to account for their prescribing errors in secondary care (Dornan et al., 2009, Lewis et al., 2014, Ryan et al., 2014) . Another study conducted in an English hospital examined the causes for prescribing errors. Insufficient training and work load errors as well as others, were

shown to be significant (Dean et al., 2002a). No previous attempts have been made to address the causes of prescribing errors by medical and non-medical prescribers in the context of electronic prescribing systems.

Owing to the relative newness of EPSs in many health care organisations, it is necessary to understand how prescribing errors arise from medical and non-medical prescribers, and a qualitative approach was chosen to explore in depth prescribers' views. This qualitative study was aligned with the previous systematic review and quantitative study of pharmacists' interventions, providing a third perspective on electronic prescribing using a different methodological approach. Using these different methods enables triangulation of findings to present a better understanding of the area of research (Mays and Pope, 2000).

The present study examined, using an in-depth qualitative approach, the causes and associated factors of electronic prescribing errors in one hospital. It aimed to explore perceptions of medical and non-medical prescribers towards the electronic prescribing system, as well as their suggestions on the system design issues to reduce prescribing errors.

4.2 Methods

4.2.1 The study setting

This study was carried out in the same setting as the work in the previous chapter. Details of the setting are in chapter 3.3.1. and the electronic prescribing system is described in chapter 3.3.2.

4.2.2 Interviewees

All medical and non-medical (pharmacists and nurses) licensed prescribers working in the hospital wards, who are using the system, were eligible for inclusion.

The prescriber types approached in this study were:

- Junior doctors: To include all training and non-training grades, which are Foundation Year 1 and Foundation Year 2, Specialty Registrars, Junior Specialist Doctors.
- Senior doctors: To include Staff Grades and Consultants.

- Independent Prescribing Pharmacists who appear on the Pharmacy Register.
- Independent Nurse Prescribers who appear on the Nursing Register.

4.2.3 Recruitment of the participants

Participants were contacted via email through the study contact based at the hospital. The researcher was unable to contact participants directly owing to data protection and hospital research ethics restrictions. In December 2016, the study facilitator was requested to forward the email to all medical and non-medicals prescribers at the Trust. All responses were forwarded to the researcher via the study facilitator.

All prescribers who expressed an interest later received an email consisting of an invitation letter (appendix 4) and participant information leaflet (appendix 5). To improve and maintain response rates, these emails were personalised to the participants (Oppenheim, 1992). Additionally, participants were provided with the contact details for the research team, which would allow them to raise issues and seek further clarification. Participants were recruited until data saturation was achieved. In qualitative research, the concept of data saturation was introduced by Glaser which refers to the data can collected till reach the point when there will no new additional data can be found (Glaser and Strauss, 2017).

Once the prescriber accepted to participate, an interview was arranged at a mutually convenient time. Before the interview commenced, participants were required to read and sign the consent form.

4.2.4 Prescribing Errors Case Studies

Owing to the potential accusatory nature of the topic, case studies were designed instead of direct questions. This approach was considered more effective as participant might not be willing to talk comfortably about their own prescribing errors. Three case studies were designed based on events that had occurred previously at the trust and contained prescribing errors (appendix 6). These were used to discuss potential causes of the errors with the participants. Before being used in interviews, the case studies were piloted and validated for clarity and comprehension by the research team and study facilitator.

Several key issues were considered with respect to participant recruitment. These were:

- The researcher did not blame any interviewee for committing an error.
- All interviews were arranged at a time convenient for the prescribers.
- Before the interviews commenced, all participants had been reminded to keep responses anonymous.

4.2.5 Data collection

Although focus groups would have provided valuable data, time constraints prevented the use of this technique. The varied shift patterns and workload made arranging focus groups practically difficult, and focus groups were considered too open a forum to allow frank discussions about prescribing errors. Semi-structured interviews were chosen instead to as they allowed for more flexibility in appointments and provided a more confidential setting to discuss prescribing errors.

Semi-structured interviews allow for researcher-led discussion, which provides more flexibility to lead questioning and seek clarification (Holloway and Galvin, 2016).This kind of approach allows the researcher to explore issues arising spontaneously during the interview (Berg, 2009, Ryan et al., 2009).

The interview guide was designed using CIT (critical incident technique) (Flanagan, 1954) and modified questions previously used in studies investigating prescribing errors (Franklin et al., 2011, Lewis et al., 2014) and later piloted to ensure the clarity and comprehensiveness (See appendix 7). This technique was chosen as it helps the researcher to collect empirical data on the causes of prescribing errors which albeit depends on self-reporting elicited by interviews with prescribers.

Face-to-face interviews were conducted using CIT to collect qualitative data regarding the causes and contributing factors for prescribing errors in an Electronic Prescribing System.

The interviews were conducted between 5th December 2016 and 25th April 2017 in a quiet room in the prescriber's department.

Before the interview commenced, the researcher provided the participants with a brief explanation about the purpose of the study and what to anticipate during the interview.

Participants were requested to verbally confirm that they read the Participant Information Leaflet and had signed the consent form. Upon completion, participants were provided with the case studies to analyse and find errors. Before discussion with the researcher regarding this, each participant was asked if they were willing to be audio-taped and reassured that any information supplied would be treated in the strictest of confidence.

The discussions lasted between 20 to 30 minutes and no confidential information was recorded in the transcript.

4.2.6 Data Transcription

Interviews were recorded on a digital recording device. The recordings were transcribed verbatim by the researcher (FA) and the accuracy of the transcripts was checked by the principal investigator (FA) against these. After transcription and final analysis, the recordings were deleted.

4.2.7 Data Analysis

To maintain confidentiality, all transcripts were treated anonymously, coded and later underwent thematic analysis. Analysis was conducted on NVivo® version 10.

Based on the interviewees' responses as well as the framework for analysing risk and safety in clinical medicine (Vincent et al., 1998), a coding framework was generated. Inductive and deductive analysis was used in this study, to develop a thematic analysis of the data. Themes of causes of electronic prescribing errors were utilised using the deductive approach. The emerging themes explored from the interviews about prescribers' perception, attitudes, concerns, and feedback on system were utilised using the inductive approach. From this a series of inter-related concepts to describe interviewees' relationship with, and experience of, electronic prescribing was generated.

The framework supported direct quotes from the interviewees and these were allocated specific codes. The coding framework was checked for accuracy by the supervision team members (JM & AC) with any differences resolved via consensus. Common themes were emphasised using direct quotes.

4.2.8 Ethical approval

The study was approved by the University of Birmingham Research Ethics Committee and by the Research Ethics Committee at the NHS hospital trust (ERN_15-0161).

4.3 Results

A total of twenty-three medical and non-medical prescribers were interviewed. Five senior doctors, 5 junior doctors, 6 nurses and 7 pharmacist independent prescribers. 10 males and 13 female prescribers (Table 4.1).

Table 4.1 Summary of study participants.

Interviewee Code	Gender	Speciality	Years
Senior 1	Male	Endocrinology	6 years
Senior 2	Male	Acute Medicine	>10 years
Senior 3	Male	Anaesthesia	>10 years
Senior 4	Male	Internal Medicine	6 years
Senior 5	Male	Surgery	8 years
Junior 1	Male	Ear, nose and throat	1 year
Junior 2	Female	General Medicine	2 years
Junior 3	Female	Acute Medicine	1 year
Junior 4	Female	Acute Medicine	< 1 year
Junior 5	Male	General Surgery	2 years
Nurse 1	Female	Renal	>10 years
Nurse 2	Female	Renal	1 year
Nurse 3	Female	Nutrition	6 years
Nurse 4	Female	Nutrition	>10 Years
Nurse 5	Female	Genito-urinary Medicine	7 years
Nurse 6	Female	Palliative Care	1 years
Pharmacist 1	Male	Urology	2 years
Pharmacist 2	Male	Infectious	6 years
Pharmacist 3	Female	Renal	3 years
Pharmacist 4	Female	Endocrinology	2 years
Pharmacist 5	Female	Critical Care	7 years
Pharmacist 6	Male	Renal	1 year
Pharmacist 7	Female	Respiratory	< 1 year

4.3.1 Part 1: Causes of electronic prescribing errors

Results on causes of electronic prescribing errors yielded six high-level categories: the computer system, the individuals, the patients, the task, the team, and the work environment (Figure 4.1). Each of these factors are discussed below.

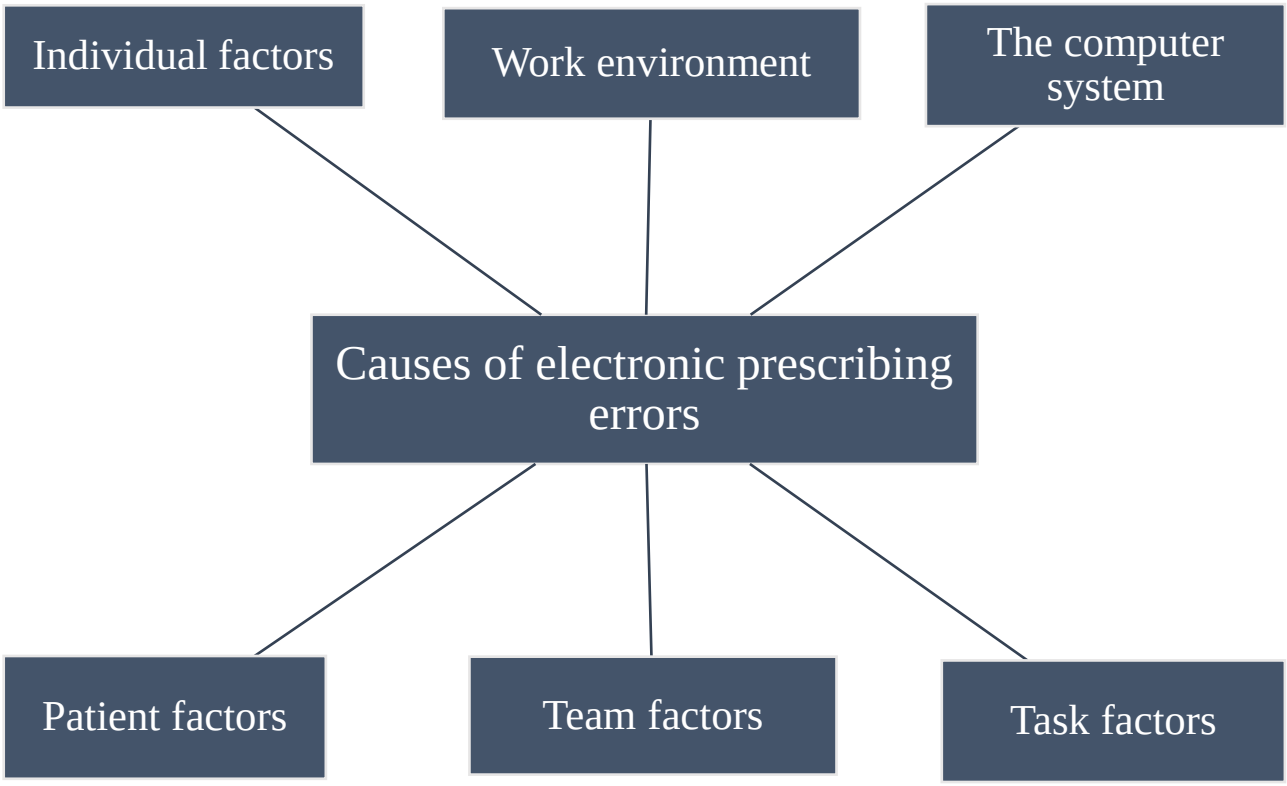


Figure 4-1 Summary of causes and contributing factors of electronic prescribing errors.

4.3.1.1 The computer system

Most prescribers in the present study felt that electronic prescribing systems reduced prescribing errors overall, although they noted that errors in prescribing could still occur. The types of errors that prescribers noted in the e-prescribing system they used included: selection

errors, auto-population information errors, overreliance on the system, remote prescribing, alerts fatigue, complexity and inflexibility of the system, and system feed errors. Most of these factors are interconnected.

4.3.1.1.1 Drug Name picking errors

Selection of the wrong item from an electronic dropdown list was identified by most of the interviewees (18/23). Juxtaposition errors, whereby a medication listed before or after the desired medication is erroneously chosen, was mentioned as a cause of prescribing errors. This would result in orders being placed for drugs with an entirely different indication than intended.

> *"…because you're clicking so fast. And when you've got a lot of work to do, it's easy to click on the wrong drug, not double check it and just click again and obviously you are responsible for that's being tracked, uh, and I think when you are doing written prescribing, you know what you're writing. Whether you write it fast or slow, you know what you're writing so I think that's…"* **Junior 2.**

Inadvertent mouse wheeling by selecting an incorrect item was mentioned as a contributing factor of prescribing errors.

> *"…there's always the error of just clicking the mouse in the wrong place or, you know, the mouse might be … that isn't working properly, you know, you're trying to get the, the curser to move and it's, and it's not, and it's not moving properly."* **Nurse 4**

Prescribers noted that the auto-completion medication name functionality is a contributing factor. This feature suggests drug name on entering the first few letters of a drug name, then the system "suggests" drug name, which could be easily selected in error. Some noted their own attempts to avoid this problem.

> *"…when you start typing, you just type the first few letters and it comes with a drop down menu. You could click on the wrong one, so I normally try to type in as many of the letters as possible so that just one is on the drop down thing, so you don't click the wrong …As much of the word as possible, so you could- because then you could end up prescribing amiloride instead of amlodipine or something."* **Senior 2**

4.3.1.1.1.1 New technology devices

With new technology innovations, prescribers can prescribe using a touch screen computer. Prescribers noted that they might make prescribing errors when locating the drug on the monitor, by touching the wrong icon.

> *"you could pick wrong things, do wrong things, type wrongly, make wrong errors because of the touch on a screen."* **Pharmacist 1**

4.3.1.1.2 Auto-population of e-prescription information

Interviewees described how the auto-populate features of the electronic prescribing system, would auto-populated drug information such, as drug dosing frequencies, to the default. Some participants believed that other prescribers let defaulted fields stand, rather than correcting them, to avoid conflict with the e-prescribing system.

An example of prescribing error from auto-population is given here.

> *"I had a patient that was prescribed baclofen. We changed it from tablet to oral solution. They were on 10 mg once a day before they changed it, so it was prescribed fine on PICS, baclofen 10 mg tablets once a day. But they had swallowing difficulty, so we changed it to oral solution which defaulted the dose to 5 mg of TDS."* ***Senior 2***

4.3.1.1.3 Overreliance on prescribing systems

Overreliance on the safety features of electronic prescribing systems was reported as a cause of errors. Some prescribers perceived reliability and trust in the technology to contribute to prescribing errors. Overreliance or complacency on the technology to detect errors were also mentioned. One participant reported that errors arise owing to prescribers possibly being complacent toward the electronic prescribing system, since they felt individuals expected the system's safety measures to prevent errors.

> *"such errors occur mostly due to complacency. Because I think there is a lot of, you know, a lot, of kind of measures in place to prevent errors occurring in electronic prescribing, um, and there's a lot of you know alerts and things like that that come up."* **Nurse 2**

4.3.1.1.4 Remote Prescribing

Remote prescribing was identified as a source of prescribing errors. Prescribers have the ability to prescribe for patients remotely rather than attending the ward and assessing the patients and checking for appropriateness for medications being prescribed. This led to a disconnect between the act of prescribing and clinical assessment of the patient.

> *"if you prescribe something without assessing the patient, so if someone rings and says oh, they need some painkillers, you might prescribe a painkiller that they shouldn't have, based on their clinical picture."* **Junior 3**

4.3.1.1.5 Alert Fatigue

Alert fatigue was identified as a contributing factor of prescribing errors. Too many alerts caused prescribers to override both important and unimportant alerts in a manner that compromises the desired safety effect of electronic prescribing systems. Interviewees expressed this clearly, and the potential harm it might cause:

> *"After a while, you get used to the warnings, so you, sometimes, you probably don't read them as well as you should so you just keep clicking the warning off and you might miss a warning and still prescribe a drug for a patient that probably shouldn't be having it."* **Junior 3**

Users become fatigued by excessive numbers of inappropriate alerts, and consequently may bypass warnings that could prevent errors. Prescribers reported that they do not only override irrelevant alerts but also relevant ones which could lead to errors.

> *"I think people can get pop up fatigue and then that leads them to just accept, accept, accept, through the pop ups and then you sort of start to miss the important pop ups, so I think you have got to be careful about the level you put that too."* **Junior 4**

Too many alerts caused prescribers to ignore important and clinically unimportant ones. Prescribers reported that they do not pay attention to the warning messages unless it is a hard-stop that needs to be signed.

> *"..there's little pop-ups come up around, but we get ... you get pop-up fatigue, in the sense that you stop reading them after a while; you just press okay all the time, unless you actually have to type your name to it. So that-that always happens with, uh, prescribing medications."* **Senior 4**

4.3.1.1.6 Complexity of the system and inflexibility

Prescribers noted the complex nature of electronic prescribing system, and how the complexity and rigidity of the system in prescribing some medication has the potential to lead to errors.

> *"There's a few things on there that aren't intuitive and I still don't know why the system does it like it does. So for example, the, you know, the ability to administer some crystalloids in normal saline but with 40mls of potassium in, that isn't in the dropdown list for crystalloids fluids, it's not an option. You have to give, you have to prescribe 40mls of potassium as a drug and then give a fluid with it."* **Junior 5**

Prescribers noted that electronic prescribing is inflexible, once system rules are in place which remove flexibility from the system. An example was described where the duration of antibiotic prescribing generated a duration of treatment error.

> *"Uh, but still, you can see how errors can happen. One of my patients who needed long-term antibiotics for about six weeks, uh, but the system will not allow you to prescribe more than three weeks, and by the end of that three weeks, because team were not aware, the patient missed a few doses of antibiotics."* **Senior 5**

4.3.1.1.7 System feed errors

Prescribers reported that it was easy to provide the system with wrong information which will lead to prescribing errors. This occurred during the data entry phase of the initial data entry to create the prescription e.g. drug choice, dosing, or duration of the treatment.

> *"when you prescribe something, uh, on the system, it drops off ,you know, if you've given it an end date. But it might be that you want it for longer so you end up getting unnecessarily long courses or unnecessarily short courses where people have missed…"* **Pharmacist 2**

In some circumstances, a medication is a non-formulary item, so prescribers can do a "dot prescription" which allows the prescribing of a medication not listed in the hospital formulary. This kind of prescription avoids the error detection systems of the e-prescribing system, and no alerts will be triggered.

> *"if you do a dot before it and then free type the drug, but again that might lead to more errors because when you free type there's not as many, alerts that come up because sometimes you get alerts and things in the system."* **Pharmacist 4**

Prescribers noted that errors can occur by picking the wrong patient and prescribing medications for that patient. This could occur as the health care professional could select a non-intended patient from the list as they are next to each other in the screen and prescribe the correct medication.

> *"one of the things that can go wrong is that it's very easy to be in the wrong patient record when you're selecting. So when you are prescribing on paper, you would be at the patient's bed space and you would only have their charts in front of you."* **Pharmacist 5**

Prescribers also reported that they forget to log out from the previous patient's record and sign in the next patient's medical record. An example was reported by a prescriber who was distracted by another staff to prescribe a medication using the wrong patient record.

> *"if someone comes and asks you a question about another patient you might open their record and then someone comes and asks you another question and wants you to prescribe something and you're in the wrong record and you could make a prescribing error that way"* **Pharmacist 5**

Using a bed number instead of a patient's name was reported as a source of errors. Choosing the wrong patient bed number from the list of patients could occur as they are listed next to each other on the system.

> *"… one of the errors. They might, for example, prescribe under the wrong patient's name. I've seen that before. someone's written a discharge letter under the wrong name before. So, I think yeah, there is some errors there. It's very easily done, um, bed 12, bed 13. Very close together on the system and they can prescribe the wrong thing. For example, where the patient's name is exactly the same."* **Junior 4**

Data entry errors could be in many forms. An example was mentioned for prescribing errors when choosing a wrong medical record number or choosing the same patient name without confirming of the name that was chosen could cause issues.

> *"And a lot of time a simple thing like doing everything correctly but selecting the wrong patient, for example. You know, you open up, , a prescribing system, 2 or 3 or 100 patients with the same name, and, you know, you may have a system where you, you've checked the hospital number and you made an error of one number, and it's a different patient. You know, you've looked at a date of birth, made an error with one number, and now you've got a different prescription."* **Senior 3**

4.3.1.2 Individual Factors

Analysis of the interviews found 8 factors likely to have an impact on individual prescriber's risk of prescribing errors. These were: knowledge and experience, busyness, lack of documentation, slips and lapses, negligence, stress and tiredness, violations, and training.

4.3.1.2.1 Knowledge, experience and training

The most frequently reported individual factor was the lack of a knowledge base that integrated scientific knowledge with clinical knowledge. Lack of knowledge included deficits in drug knowledge for appropriate drug dosing (e.g., giving the wrong dose for renal or older patients) and failure to apply a protocol (e.g. modifying the dose in the presence of renal failure).

> *"there would have needed to be a knowledge by the prescriber about the correct dosing of the Enoxaparin and really you should not need a computer to…I would expect a doctor in renal medicine to know what the correct dose was and prescribe the correct dose."* **Nurse 2**

The clinical knowledge reported as necessary for prescribing treatments for patients included knowledge of drugs, doses, and patients' conditions and existing medications.

> *"if you're prescribing in a certain area of your specialty or expertise, you might not quite understand other co-morbidities and how other medications might affect."* **Nurse 6**

Lack of knowledge of some medications was mentioned as a cause of errors. For example, junior doctors may rely on their seniors when they prescribe a medication. This may lead to dose regimen errors. Professional hierarchy resulted in reluctance of junior staff to question their seniors, perhaps owing to a lack of confidence or reluctance to exhibit a lack of knowledge.

"if you don't know about the drugs, you're going to make mistakes. It is as simple as that. The doctors will—some doctors for example will be asked by their seniors, tell them to prescribe something. They will go and prescribe whether they heard it correctly, not heard it correctly understand what they're doing, don't understand what they're doing. If they don't understand what they're doing, they're more likely to just do something without realising what they're doing." **Senior 1**

Apart from clinical knowledge, lack of computing skills in handling technology were stated to contribute to the same error. Lack of adequate training on how to use the system and how to rectify an error being made was reported as a cause of error.

"…understand and do it electronically , you need to have people with computer skills…The literacy , the skill needed to be able to do it , and you need to understand if I made an error, how am I be able to get myself out of the error before it reaches the patient." **Nurse 1**

4.3.1.2.2 Busyness

Human memory was reported to contribute to prescribing errors, due to limitations including forgetfulness and lack of attention. Being busy and working through the night caused doctors to be tired and to forget to prescribe.

"if the doctor is very busy and particularly they're on call and they have got a lot of things to do; they tend to forget things, we're human beings and we tend to forget things and when you forget, you make errors." **Senior 1**

Prescribers reported that working in busy environments and with high work load caused them to try to do their task in a rushed manner leading to prescribing errors.

"when you're busy and you're, you're trying to click things quickly, maybe if you're very familiar with the system, you might be very quick at prescribing different drugs, and all it takes, as you say, is for you to select the wrong, you know, frequency of administration from once a day to twice a day - And, you know, it, usually the system picks it up if that's, not a known, , you know, concentration or, or frequency of delivery." **Junior 5**

Being rushed and busy were the two most commonly mentioned causes of prescribing errors. Rushing and lack of time were also mentioned as a source of errors.

"if you're busier and you've got a bigger workload, then you're just rushing to get things done, you don't necessarily take time or take enough care to double-check that you've prescribed the correct thing. " **Nurse 3**

4.3.1.2.3 Lack of documentation

Failure or inadequate medication documentation upon patient's admission was reported as source of prescribing errors. Pharmacists claimed that prescribers do not do medication reconciliation which might lead to prescribing errors.

"they don't even go through the meds with the patient; they just write it down on the clerking, prescribe everything, and then we then, we can see all the meds as pharmacists." **Pharmacist 7**

The failure to document drug allergies onto the system and poor history taking upon admission was reported as a leading cause of prescribing errors.

"*the very basic prescribing error is, um, first off, um, people don't write allergies down"* **Senior 4**

4.3.1.2.4 Slips and Lapses

Prescribers reported that errors were caused by slips in attention or lapses of memory. Memory lapses included situations such as forgetting prescribing a medication to which a patient has an allergy.

> *"I've put in a, a penicillin allergy and then I've gone to prescribe Augmentin and I've, you know, you go to do it and then just stop yourself."* **Junior 2**

Prescribers also reported that slips or lapses were more likely to occur when they were busy, tired, or distracted.

> *"I think sometimes it would be if a person's not paying attention to details or in a rush. If someone is busy and they are not paying attention to details because they are trying to make the target, that might be a contributing factor."* **Nurse 5**

Forgetting to navigate from the current patient's profile to prescribe for another patient was reported an example for slips.

> *" I saw four patients. The nurse comes to me. I've got PICS opened up and nurse tells me that your patient has got a heart rate of 200. So I want to prescribe a beta-blocker. Then I look for the patient but I usually don't concentrate because I'm still stuck with another patient. In the, doing the work, I'm looking after another patient and I'm prescribing medicine in another. So I ended up prescribing a medicine for my patient, the one who I was looking after now. So these are very common errors I see."* **Senior 2**

4.3.1.2.5 Negligence

Negligence or failure to follow standard of care was identified as a contributing factor to prescribing errors. Unfamiliarity of how the system works and being negligent as prescribers are accustomed to a paper based system may lead to errors on prescribing medications.

"it's because people don't understand how electronic prescribing system works, they don't know how to read and follow through because we are so used to paperwork and people are not really, I hate to say this , but people do things without even reading exactly what they are doing , that could cause an error." **Nurse 1**

Negligence or recklessness by over reliance on other colleagues were thought to have played a part as well. One scenario was reported to omit required medications intentionally.

"if you're on call and you're very, very busy, quite often, the junior doctors won't prescribe all the medications for their patients because they see that as not necessarily their job." **Senior 2**

4.3.1.2.6 Stress and tiredness

Prescribers' emotional status and their stress and tiredness were described by them as being likely to contribute to an error.

"Yes, stress, push it from every side that see more patients, see more patients. There's a lot of mistakes. Um, commonest mistake happens is that we prescribe one patient's medication to the other one on the PICS" **Senior 2**

Prescribers stated that physical or mental status for being tired, hungry, thirsty, unwell or with low mood at the time prescribing will contribute to errors.

"tiredness makes a huge difference. It affects your concentration. If you've had a really horrible, busy shift and you are absolutely drained and then you've got to try and concentrate" **Nurse 4**

4.3.1.2.7 Violations

Rule violations were reported as failures to follow accepted prescribing rules by prescribers will lead to errors. Prescribers sometimes tend to postpone standing orders to the next shift causing a backlog of work to the staff working on the next shift.

> *"if they're very tired, um, and they have too many things to do, um, they tend to leave things for the following morning, so the medication has not been given, this not important that can wait 'till tomorrow. Where I am not sure, I don't have time to spend so much time to dig into it and explore it."* **Senior 1**

Violations were mentioned which occur when individuals for personal gain, self-autonomy or for their ego, such as deciding to break a rule to demonstrate skills at a particular task.

> *"bad habits perhaps could be one of them, so you're consistently doing things very quickly, excessively quickly uhm, trying to rush things, or perhaps even confidence that I'll … yeah, this will do, this is fine, I'm … I'm a doctor, I don't mind the patient being on this dose even though it's an error, now error being different from what they normally have rather than error being on this dose even though it's an error…"* **Senior 4**

One scenario of violation was reported to omit required medications intentionally.

> *"if you're on call and you're very, very busy, quite often, the junior doctors won't prescribe all the medications for their patients because they see that as not necessarily their job."* **Senior 2**

4.3.1.2.8 Lack of training

Lack of training on using the system was mentioned by all grades of prescribers as source of prescribing errors. One interviewee reported that he had not received a formal prescribing training session.

> *"…training for new members of staff. So, um, it has to fulfil its responsibility and sometimes the trust is just trying to tick that box yes we gave you training and now it's your problem where sometimes training can be a bit intense."* **Junior 1**

Other interviewees held quite negative experiences of their training. It was claimed that the training session on the system was inadequate and short. Hence, a prescriber was expected to figure out how to use the system independently.

> *"we use a system called PICS. So, the thing is, again, the training before you start prescribing, you've got only 30 minutes training and then you have just to try to practise by yourself. I guess that might affect, because sometimes if you're not used to the system, yes, it is likely that you might make small errors."* **Nurse 5**

As the system is complex, refreshing training session was suggested by some respondents to improve prescribing to reduce prescribing errors.

> *"..that's the main training that we have. Um , it'd be good to have a refresher, after a certain… like maybe a year, yearly refresher and everything."* **Pharmacist 7**

4.3.1.3 Patients

Analysis yielded that patient factors contribute to prescribing errors. These factors were: complex clinical conditions, patient is unhelpful, and familiarity of the patient.

4.3.1.3.1 Complex clinical conditions

The complexity of the case and the specific medications to be prescribed were mentioned as a cause of prescribing error. Patients with comorbidities are more likely to receive medications that can have a negative influence on other comorbidities. Consequently prescribing errors occur as a result of limited treatment plans option that may have an influence on such comorbidities.

> *"if the patient, like if it's a complex case then when you're prescribing obviously you need to look into, you know, contra-indications, and, uh, drug interactions and these things and obviously if the patient is on more drugs and they've got more things which could limit your prescribing window, for example, if they've got, um, kidney disease which means they can't have certain medication. If they've got asthma which means they can't have certain medications as well um like beta blockers or something like that … then obviously these things do affect your, uh, increase your chance of prescribing errors"* **Junior 1**

The complexity of the individual clinical cases (acuity) was mentioned to contribute to prescribing errors. An example was reported by a non-medical prescriber of resulting errors due to the change of normal route.

> *"on the critical care particularly the routes that are normally available on the ward are not always appropriate for my patients. So, something that they were previously swallowing is now going down a nasogastric tube – so, we have to make a lot of dose adjustments for going between IV and oral routes or oral and entral-routes, so there are quite a lot of errors there"* **Pharmacist 5**

The complexity of the case as well as a lack of deeper understanding of patient's current therapy or lack of knowledge of the prescribers of the drug-drug interaction was mentioned as a factor of prescribing error.

"it more complicated if they've got lots of other therapies going on and as a non-medical prescriber, obviously, we only know our little bit about our own therapy, we don't know enough about the other therapies." **Nurse 3**

4.3.1.3.2 Patient is unhelpful

Some prescribers reported that errors arise when taking medication history from the patients as they might give it inaccurate or might be wrong which lead to prescribing errors.

"Sometimes patient's think they're on a specific dose, but they're not on that dose, so you might go from patient information and then you prescribe the wrong dose, but it's on what the patient said as well." **Junior 3**

Also, in some situations, patients are not able to give their medication history due to their status e.g. unconsciousness.

"..patient, if he's confused and we are unable to pick up the information properly, they can give us wrong dosing and we can prescribe. Plus patients are usually, means, elderly patients usually are not very well aware of the medication itself." **Senior 2**

Prescribing errors were reported to occur when medication history is unavailable or irretrievable during the clerking of patients being admitted to the hospital. Delayed prescribing of medications to patients and waiting to the next day may cause omission of prescribing medication which will lead to prescribing errors.

"it becomes a detective case and, and again, that's not a very safe way of prescribing because, but, you know, the ...You're faced with, out of hours you're faced with the option of not prescribing any drugs - and waiting for the next day until the GP surgery opens or a family member can bring in the prescription. So you've got the dilemma of

leaving a patient without potentially important medication for 12 or 18 hours or guessing and you know, what you're trying to work out." **Junior 4**

Several prescribers noted difficulties in prescriber – patient communication as an important cause of error. Communication barriers or lack of sufficient information about current medication from the patient was also noted as a cause of prescribing errors.

"if you've got a patient who isn't communicative, if you've got a patient who you can't find what they're usually on, um, if you've got a patient who doesn't have their own medications with them, then that can contribute to regular, you know, their regular medications' prescribing errors." **Pharmacist 3**

Prescribing errors were suggested to be related to communication barriers between the prescriber and the patient due to difficulty in understanding essential information at the time of prescribing.

"The other issue is the patient themselves, there's a communication barrier, they don't actually understand what you're asking, then, what you are explaining to them, and that in itself could be a contributing factor to the prescription error." **Senior 3**

4.3.1.3.3 Familiarity with the patients

Prescribers reported how unfamiliarity with the patients contributed to their prescribing errors. Treating a patient who is treated by a different medical team during on call, was a common example given.

"it happens when you're on call and you're asked to do something for a patient from different wards, you're on call, .. you're just covering them on call and something happens, struggling to think of a specific case but you, we get it all the time, you know. You're asked to prescribe this or, you are asked to see them because they're

deteriorating, you want to prescribe this or that, and you don't know them as well. " **Junior 2**

4.3.1.4 The task of prescribing

In this section, the analysis revealed that task of prescribing causing errors. These factors are as follow: drug history unavailable, lack of protocols, test results unavailable, and transition of care. They are discussed below.

4.3.1.4.1 Drug history unavailable

Prescribers noted the errors occur because the medication history in unobtainable, especially after business hours or late at night as GP Surgeries are closed and the patient is too ill to obtain an accurate medication history. Patients were often are unable to report their drug medication history accurately. Lack of access to the summary care records were identified as a contributing factor of prescribing errors.

"when patients come into hospital sometimes they come in really late at night, so it's really hard to obtain drug histories because the GP surgeries are closed the doctors don't have access to summary care records so it's hard for them to get a drug history properly especially if a patient comes in when they're confused….I've seen that sometimes patients say oh, I'm on bisoprolol but they don't know the dose, so the doctors just prescribe bisoprolol and they just go with the default on PICS" **Junior 4**

Lack of adequate sources of medication history and discrepancies were also reported as a cause of prescribing errors when taking medication history from the patient or outdated sources.

"how good a history they're able to give, with or without collaterals from their family. Um, I mean often we can go to other sources for medications like the GP records and things, but sometimes, if that is quite out of date and the patient is not certain, that can lead to some problems." **Junior 4**

Prescribers noted that some medications (such as morphine or HIV medications) are not shown on summary care records or cannot be obtained from the GPs as they are not being prescribed by them which could lead to medication omissions.

> *"Summary care records aren't always accurate, um; they don't include morphine doses. They don't include insulin doses, um, which is foolish, in my eyes. And if a patient's on any HIV medications that have been prescribed by the hospital, not by the GP practice, that isn't on it. And so there are quite lot omissions on summary care records…"* **Senior 4**

4.3.1.4.2 Lack of Protocols

Lack of protocols and guidelines of prescribing medications as reference to refer to was mentioned by prescribers as a cause of errors.

> *"if you don't have protocols, you don't have guidelines and you don't have the right guidance; there is going to be mistakes being made because there's nothing for the doctors or the prescribers to refer to.."* **Pharmacist 1**

The complexity of accessing or obtaining the available protocols was noted by prescribers as a source of errors. An example was mentioned by a senior prescriber that some guidelines can only be accessed if you have the right abbreviation initially uploaded to the system.

> *"if I want to work out how I need to prescribe the, um, the, uh, a, uh, a novel anticoagulant for someone who's got a deep vein thrombosis okay? I need to know the exact word that that doctor who uploaded that, uh, guideline used. So if I wrote deep vein thrombosis, it won't come up. If I wrote thrombosis, it won't come up. If I … I have to write VTE."* **Senior 4**

4.3.1.4.3 Test results unavailable

Prescribers noted that errors can occur when they want to prescribe a medication without essential laboratory results (especially abnormal results). Lack or delayed vital diagnostic confirmation results was mentioned by prescribers as contributing factors to prescribe wrong medications.

> *"So sometimes, um, you'll prescribe a medication before the blood results are back. So you may put someone on xxx before they know that they've got acute kidney injury. You might put them on a diuretic before they know they've got acute kidney injury. You may put them on, um, a, um, azathioprine, um, um, or ... not azathioprine. Um, you may put them on, um, some of the chemotherapy agents, not knowing that they might have cancer, so.."* **Senior 4**

4.3.1.4.4 Transition of care

Prescribers noted the difficulties of sharing or transferring information between hospital and primary health care. This inability to access patient record between the community and hospital settings was raised as an issue leading to prescribing errors.

> *"I mean there is always the barrier in certainly between community and hospital. We don't have access to their records, they don't have access to our records."* **Junior 4**

Data from the primary care can be unreliable and can lead to prescribing errors. Outdated discharge summaries as well as the therapeutic modifications that have been made by GPs or by out-patients prescribers are not updated to be an accurate source of medication history. This will contribute to prescribing errors as well.

> *"There are other sources, obviously GP records, previous discharge summaries, um, but even that can be tricky because you look at a previous discharge summary from a year ago, and then from that year until now, the GP might have made some adjustment,*

or another consultant has seen the patient and our patient has made some adjustment, but the GP record hasn't been updated. Or the, um, the discharge summary was before that consultant review." **Senior 1**

4.3.1.5 Team Factor

Prescribers described how factors relating to team performance could contribute to prescribing errors. These team factors include poor communication, staffing levels, and supervision from more experienced prescribers.

4.3.1.5.1 Poor communication

Poor communication between health care team members influences the occurrence of prescribing errors. Several prescribers highlighted the importance of communication between health care providers or between team members to avoid the errors. The way of the communication between team members when giving an order as they use the bed number instead of patient's name was reported to cause prescribing errors.

"if someone has told you—so you mix them up, yeah, so if someone has told you bed 4 needs paracetamol and bed 5 needs codeine, you might mess it up. Especially when they don't use names, if they use bed numbers, you could mix it up because it is a pressured environment" **Junior 3**

Inadequate communication between healthcare professionals was also an important predisposing factor when patients being transferred from a ward to another or handing the patient over at the end of shift was noted as a cause of prescribing errors.

"on transfer to a ward, from ITU to a general medical ward, it seems they should have been reviewed on, on transfer by someone. And it was failed to, it, you know, it wasn't noted there either." **Junior 2**

4.3.1.5.2 Staffing

Staffing level issues were also mentioned and included inadequate staff, staff turnover and providing cover for absent colleagues have been mentioned as increasing workload and errors provoking. Low staffing that need to meet work assignments was thought to be a contributing factor to cause errors.

> *"…because of the pressure of we working in the NHS, you know , less staff and more patients but, at the end of the day, we have to do what we have to do and the way we do it we have to do it to the best of our ability."* **Nurse 3**

4.3.1.5.3 Lack of Supervision

Some junior doctors and non-medical prescribers felt that lack of supervision lead to prescribing errors. In some cases, if a prescriber (junior doctor) is asked by a senior doctor to prescribe a drug, who did so without asking questions, assuming that to do so was correct.

> *"if you're working in an area where you don't feel like you can ask for help if you're not sure, then errors are going to be made, because somebody could do something because they feel they've got to get it done because they've been asked to do it and if they're not entirely sure what they're doing, then there's always the potential for it to go wrong."* **Nurse 4**

4.3.1.5.4 Work Environment

Interviewees suggested the working environment is a major contributor to prescribing errors. Work load and time pressure was most commonly raised. The work environment was identified as an important aspect by all prescribers. Heavy workload, time pressures, a chaotic environment and the need to perform more than one task simultaneously were also commonly mentioned.

> *"...working environment, that's such a huge factor which I think is probably underestimated in the sense that um if there is uh colleagues, there are colleagues who are for example you know um around you, asking you if you*

need to do this you need to do and you've got like fifty things going on, massive workload on you and you know that those things are going to and at the same time you are trying to prescribe something. You're going to make mistakes." **Junior 1**

Perceived high workload and associated distracting atmosphere during prescribing were contributing factors for prescribing errors.

"it's noisy, it's busy, it's very distracting, um so that can be a problem. Um, getting somewhere to just focus on actually being able to look at the medicines on the screen, it is quite difficult at times." **Junior 4**

Being rushed and distracted by another colleagues during prescribing was also mentioned. An example reported by one interviewee was that he was distracted by a nurse while he was prescribing. He prescribed a medication for the wrong patient.

"The nurse comes to me. I've got PICS opened up and nurse tells me that your patient has got a heart rate of 200. So I want to prescribe a beta-blocker. Then I look for the patient but I usually don't concentrate because I'm still stuck with another patient. In the, doing the work, I'm looking after another patient and I'm prescribing medicine in another. So I ended up prescribing a medicine for my patient, the one who I was looking after now. So these are very common errors I see." **Senior 2**

Perceived high workload also contributed to errors, and this was increased due to staff shortages, and busy shifts. An independent nurse prescriber considered workload, and other contextual factors, led to prescribing errors.

"if you're busier and you've got a bigger workload, then you're just rushing to get things done, you don't necessarily take time or take enough care to double-check that you've prescribed the correct thing." **Nurse 3**

Workings in noisy or chaotic environments was mentioned as a contributory factor of prescribing errors.

> *"there is chaos on the wards sometimes and the chaos on the words, especially if you have got doctors that are trying to prescribe for multiple people doing different jobs at the same time. So you're going to make mistakes."* **Pharmacist 1**

4.3.2 Part 2: Prescribers' Views and Concerns On An Electronic Prescribing System

Results yielded three high-level categories: views on system utility, human interaction with the system, and suggestions on system design to reduce errors (Figure 4.2). Each of these themes is discussed below.

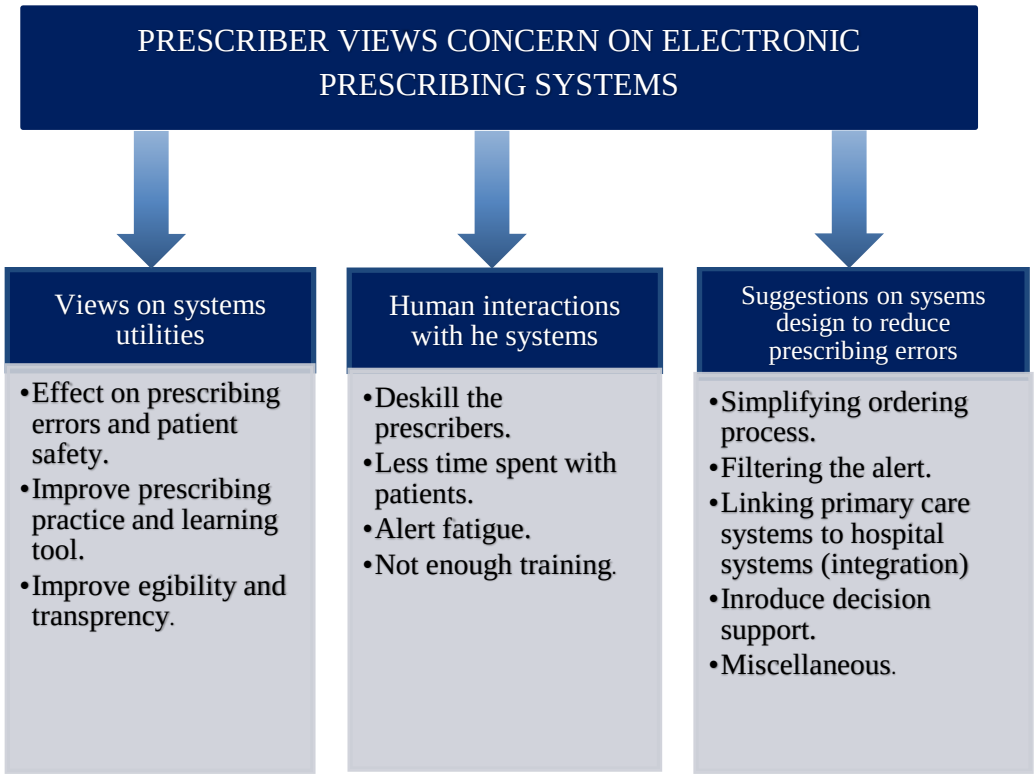


Figure 4.2. Prescribers' views and concerns on electronic prescribing systems.

4.3.2.1 Views on system utility

Prescribers had varied views on the utility of electronic prescribing. However, prescribers described impacts on prescribing errors and patient safety, improved prescribing practice and learning, and improved legibility and transparency.

4.3.2.1.1 Effect on prescribing errors and patient safety

Prescribers perceived that e- prescribing reduces common errors that are associated with paper-based prescribing, including clarity, illegible handwriting and unclear dosages.

> *"..trying to read doctors' handwriting on a prescription chart is impossible. So, at least there isn't that error made because you've got the drug name legible, the dose and everything ... you can read the prescription and you can see exactly what it is you're meant to be prescribing, because that used to be a big problem, you just could not read paper drug charts."* **Nurse 4**

It was reported that electronic prescribing systems has the quality and validity of the knowledge base which promote medication safety and consequently reduce prescribing errors.

> *"it has the knowledge base that you may not have and so it, will bring to attention certain mistakes that you may have made, that you haven't noticed or don't know about. So it helps you in that way."* **Junior 2**

Electronic prescribing in the hospital was perceived a potential intervention to improve patient safety. An example was reported related the system can capture dosing errors as it has a safety measure to act as a barrier.

> *"if you're talking about dose errors, so yes, electronic is much more safer with the dose because if you write a ridiculous dose for one of these, um, uh, one-one of these medications, the system will simply refuse it. Uh, while, uh, if you write it with your hand, you can make mistakes."* **Senior 5**

As the system has safety net feature, it was mentioned that electronic prescribing can generate alerts in to alter the dose in case of renal impairment which improve safety of the prescribing.

"you will have a pop up about the fact that the patients GFR is too low for them to have this drug. And you might miss that if you are doing that, using that paper chart." **Junior 1**

It was mentioned that electronic prescribing makes the prescriber more vigilant in interacting with the system during prescribing.

" it makes you more vigilant and then you get thinking because you know if you haven't ticked this , it will not allow you to do it, and if it keeps giving you red square, you thinking what have I done wrong, and you have to go back because it's not allowing you to do anything ." **Nurse 1**

One of the prescribers perceived that electronic prescribing does not reduce the incident of prescribing errors.

"it doesn't reduce the incidents; it just makes it easier to prescribe. I don't think it reduces the incidents of prescribing errors if anything. " **Senior 5**

It was claimed that using computerised system has introduced a new type of errors that was not associated with paper based system.

"it has introduced a few different types; selection errors for example." **Pharmacist 1**

It was believed that using electronic prescribing system, gives the prescribers a false confidence that they are prescribing the most appropriate prescribing.

"it also gives you a false sense of assurance that, you know, it's all ... it's all sorted. You could still have a human interface, and we're the flawed part of the system, aren't we?" **Senior 4**

4.3.2.1.2 Improves prescribing practice and learning tool

It was reported by one of the prescribers that electronic prescribing has improved the way of communication between all staff using the system.

"..we have a better communication with the electronic system" **Senior 3**

One prescriber appreciated using electronic prescribing as it has improved the clinical practice and workflow efficiency by saving time.

"it saves you time and also just, I remember with the paper prescriptions, if you're coming across a drug that you're not, even drugs that you, you do prescribe on a not quite regular basis but, you know, you can't remember whether it's three times a day, twice a day is it, then so that you need to go to BNF and it's time involved in finding out." **Junior 2**

Prescribers perceived that they benefit of electronic prescribing by improving the speed of access to information. Saving prescribers' time was mentioned as a positive attitudes to it which is reported in the previous quote.

Prescribers perceived that electronic prescribing system allows prescribers to do their job from any place which makes the prescribing and duties more efficient and convenient.

"You can see what's happening from any interface anywhere in the hospital and even remotely…it's much more efficient, it's much more effective." **Senior 3**

Prescribers had positive attitudes toward electronic prescribing. It was expressed by prescribers that electronic prescribing system could be used as an e-learning program to support continuous learning.

"this can be a teaching tool because when you are looking at different drugs, you know, you learn through the system. " **Junior 1**

One prescriber mentioned that using computerised prescribing system benefit prescribers to be used as an effective virtual learning tool.

"such systems they can they kind of like a, they have benefits and risks in the same area for example, um, these prompts and things can encourage, uh, there can be a learning

tool because you might click something and you know it's a reminder for you oh this does interact with this drug, I don't, didn't have that information." **Junior 1**

4.3.2.1.3 Improve legibility and transparency

It was viewed that electronic prescribing system improves prescription eligibility and transparency. This will makes prescribers more accountable for what they prescribe.

"the first thing is legibility ... is obvious. Uh, the other one is transparency in their words, and so you always know their drug has been given or not given." **Senior 4**

4.3.2.2 Human interaction with the systems

Participants identified a wide range of issues that maybe encountered with using electronic prescribing systems. The main issues identified by prescribers were: deskilling the prescriber; alert fatigue; less time spent with patients; and no enough training.

4.3.2.2.1 Deskill the prescribers

One of the concerns raised was that electronic prescribing would deskill prescribers. It was mentioned that prescriber may lose comprehensive knowledge. Interviewees suggested that prescribers could become more reliant on the system and could face difficulties without electronic prescribing systems. One consultant was concerned that doctors would not ever have to work out the doses for medication and this could deskill them.

"The reliance is increasing. The information, the knowledge of the medicine is going down. So basically, we're losing our brain for the computer and I don't have much information. Just imagine if you ask me now how does warfarin work? Unless I still read through things and unless I do, I can't tell you, or how does apixaban work. I don't know, the guidelines are being fed to the computer. You prescribe and the computer tells you that this is the guideline, you have to prescribe this. so basically, they are taking over our brain activities." **Senior 2**

4.3.2.2.2 Less time spent with patients

One of the concerns raised by prescribers with using electronic prescribing system was less time spent with patients. Using such system would eventually lead to less time spent on exploring patient issues and ensuring appropriateness of the medication being prescribed.

> *"…allow doctors to potentially prescribe medications or fluids for patients without seeing them. although they're convenient, it can be dangerous because you can just be treating the patient as a name on the screen."* **Junior 5**

4.3.2.2.3 Alert fatigue

Prescribers had unfavourable views on the overwhelming number of alerts generated by the system during prescribing. Interviewees referred indirectly to the potential for alert fatigue. It was identified as a concern which occurs when a prescriber is frequently presented with many alerts during prescribing.

It was acknowledged that using the system for a period of time the user is less likely to acknowledge the content of the alert and more likely to continue past the alert without reading its contents.

> *"it will alert you for any-any kind of problems, but what end up happening is we just ignore all the messages."* **Senior 5**

Prescribers reported that too many prescribing alerts or warnings messages causing an interruption as they attempt to carry out prescribing. It led prescribers to override and ignoring them unless this system does not allow to proceed.

> *"There are loads of them and that's why we don't read them. They come up, lots of them. Like they become red. Um, unless the system doesn't allow you, we just overlook them"* **Senior 2**

> *"when you open the PICS and you've got like 20 messages and 20 messages popped into your face and you're trying to do something urgent, your patient is desperate for painkillers or something, so you just close them and you don't read them"* **Senior 5**

Interviewees also reported that information presented in the alerts was not clinically relevant which could lead to override them as well as the most significant ones.

> *"Irrelevant messages actually make us think that the rest of the things are irrelevant as well. It comes like three pages. You can't read them."* **Senior 2**

Prescribers noted that with the excessive number of interruptive clinical alerts generated by the systems, prescribers would become alert fatigues and would override them. Consequently, it makes the prescriber in a dilemma in making the decision actually to read the alert or ignore it. Failure to recognise which alert is important to less significant ones.

> *"the double edged sword would alert, it's if you have far too many alerts, then you never ever look at any of them because there's just too many of them, so how to make a judgement as to what's critical alerts and what's non-critical alerts is"* **Senior 3**

4.3.2.2.4 Not enough Training

Training was identified as an issue with using electronic prescribing system. Interviewees shared same concern with their satisfaction with electronic prescribing system training sessions. One interviewee claimed that training undertaken was not enough and should be subjected to cover potential area of pharmacy side more rather than technical side.

> *"I think um training is the main thing with that there should be more training to use the PICS and in, you know, because most of the doctors and um, they don't go through this pharmaceutical side of training or pharmacy side of training plus that is the main problem. That knowing the system is just like, using the system, but not exactly understanding the system. So they need to have understanding of the system, that requires bigger knowledge from the pharmacy side. So they need to go through that training. So here, the training is only one day training, which is not enough. I don't think that's enough."* **Senior 1**

With continuous improvement of the system and installing new updates, prescribers recommended a continuous training on these new updates.

"I think continuous education about the new, um, updates about these systems" **Senior 5**

4.3.2.3 Suggestions on system design to reduce errors

The results showed how system design can be modified in order to make the system more safe and user friendly. These suggestions include: simplifying the ordering process, filtering the alerts, integrating the system with primary care systems, introducing decision support features, and displaying risk factors.

4.3.2.3.1 Simplifying ordering process

For the design and content of the user interface of the electronic prescribing, prescribers suggested they should be presented in a way that is user-friendly and ensures accuracy of prescribing.

It was suggested that simplifying the ordering process would reduce prescribing errors associated with using the system. One interviewee recommended that input screen should be designed in a simplified manner and not to overwhelm users with too much information during ordering process.

> *"It needs to be more simple. At the moment, it's not simple, it's quite complex. Everything is in one screen and you can't do that, and you have to struggle to do, change things on this…. There are ways you can do that but those ways are not visible clearly. They are in different icons and then in the icons, there are-there are other different items."* **Pharmacist 2**

Selecting a medication, with different dosage forms, with unclear differences between them would make a potential source of prescribing errors. It was recommended by prescribers if the medication list could be re-organised in the way is displayed if a medication has more than one formulation.

"it's a problem with [diltiazem] at the present moment, which I keep on going on about. If you prescribe diltiazem, there's all these different diltiazems, there are all different formulations of diltiazem" **Senior 4**

It was recommended that the system can be simplified. It needs to make electronic prescribing system more user-friendly, less prone to error, and aid in making correct prescribing decisions. Drug chart is confusing and it needs to be organised in a way that will less likely distract users.

"I think that the other thing for me which is a bit confusing is the drug chart and prescription so that there's a page for drug chart which tells you what's been given on the prescription…you have to move from the drug chart to see what's been given to the prescription to see what's on there and you know it's a bit confusing.." **Junior 1**

The rigidity and complexity of system to change the defaulted dosing regimens needs to be simplified.

"it does, auto-populate with a default that isn't what you want to give, and sometimes it's really hard to get around,…. It sometimes doesn't allow you to, do you really have to kind of go through a few hoops to, to prescribe it." **Junior 2**

For the concerns of selection error from the drop down menu, it was suggested if the system can be modified. This modification was to change the drug selection based on first three letters at least before display.

"I think that would have probably helped with prescribing errors' and I think probably the drop down menu if it was you know uh kind of organized in a way so it wasn't guessing and you had to put at least three, four letters in before the drug came up." **Junior 1**

4.3.2.3.2 Filtering the alerts

It was suggested if the system could be configured to prioritise alerts in a manner based on their clinically significance. One prescriber suggested that alerts should be refined and displayed according their severity like BNF.

"..that it should, if it says clearly like BN-the way BNF says, most common side effects, less common side effects, uncommon side effects, rare side effect. If it can do that, that would be helpful." **Senior 2**

It was suggested by one of the prescribers that alerts should be carefully chosen to prevent alert fatigue. Alerts should have stringent criteria, such as, drug allergy, contraindication and drug-drug interactions. Consequently, prescribers can make their decisions after carefully reading the messages.

" if you had a prescription icon as a prescription as an alert where it may highlight allergies of the patient we have or may have and drugs that are contraindicated, so they may not be allergic but contraindicated to that patient, or interventions that are contraindicated, then if that comes up in the prescription alert, then by hovering over that icon, it can give you a quick snapshot as to what the prescription issues are, and then that'll be at the back of your mind when you are making the prescriptions that you are, , managing for the patient." **Senior 3**

Interviewees reported that alerts content are set in a random way. It was suggested that these alerts should be sent to the responsible person directly.

"If I, by mistake, said accept, the poor attending physician will not know about this alert message, ,, I think that error shouldn't be directed toward me, uh, and I think somehow the system should know who looked into the system" **Senior 5**

4.3.2.3.3 Linking primary care system to hospital system (Integration)

A recommendation was raised to integrate secondary care electronic prescribing with primary care systems. This integration would allow to retrieve patients' data from different systems. This integration would help prescribers to access patients' historical data which include patient's history, previous and current medication list.

"As soon as you admit the patient, it should be a centralized system. As soon as you admit the patient, the previous discharge letter, the previous medications should show

up so that we can actually select them and we can look into previous medication but then you have to go through the icon and find it." **Senior 2**

"if the patient's medication history should actually be sucked out of the GP system and proposed on the ... on the PICS system, that would be perfect" **Senior 4**

One of the system recommendations raised by one prescriber was if the system should include details of patient's medication history, a rationale for prescribing certain items, and duration of the medications being prescribed.

"One of the problems we have at the moment is when, in our prescription system, you can prescribe drugs to the patient but you may not necessarily have on the system what they're already on and what doses they're on and what, you know, what duration it's for and when it needs to come off or whether it's going to be lifelong treatment." **Senior 3**

4.3.2.3.4 Introducing decision support

The views on introducing decision support expressed fears of introducing prescribing errors with some prescribers reluctant to use it. The major concern highlighted clinical decision support was at risk of introducing more prescribing errors.

"it's a double edged sword in that, sometimes it may be helpful but in the majority of times the chances are it'll introduce more errors" **Senior 3**

Some prescribers suggested introducing clinical decision support into the system. They think that would improve prescribing practice for certain treatment regimes.

"*It is useful, so like for the Chlordiazepoxide reducing regime, it makes my life a lot simpler, rather than having to prescribe each individual dose of Chlorodiazepoxide and look at the guideline every time, I quite like structure prescribing"* **Junior 4**

It was mentioned that the system is not integrated with patient weight, as a result dosing error may occur. It was recommended if the system could be integrated with patient weight to inform the prescriber if the dose does not match patient weight and consequently to alter the dose.

> *"you can see the weight is written, um, for the patients, but doctors don't use it or the system doesn't recognise that kind of error. So that's definitely ... can be added, which is not difficult to add an extra alert to alert the doctors to consider the weight."* **Senior 5**

4.3.2.3.5 Risk factor display

It was suggested for system reconfiguration if the allergy alerts could be replaced by a hard stop or non-proceed prescribing. As it mentioned by one prescriber, if a patient is being prescribed a medication that have been recorded allergy to, the system will not allow to prescribe such medication.

> *"..to actually develop systems or to change the interface to prevent that occurring. So for example, if, if you have documented some way, some, a patient is allergic to penicillin, the system should be configured so it doesn't allow you to prescribe penicillin"* **Senior 3**

Prescribers appreciated if the risk factors of individual patient can be displayed clearly. This feature could reduce prescribing errors and change a treatment plan if needed.

> *"it would be good if that allergies were kind of always on the page whichever page you're on the allergies are somewhere in the corner, if there's, you have to click to see the allergies of the patient."* **Junior 1**

Displaying risk factors such as poor renal function clearly for individual patient was mentioned as one of the feature that the system lacks at the present. This feature could reduce the prescribing errors.

"It probably would be good if there was icons for people that had, um, poor kidney function so then it would probably warn you that they have got poor kidney function, do you want to give that much of that drug." **Junior 3**

4.3.2.3.6 Miscellaneous

The importance of the technical staff incorporating prescribers' views when designing a prescribing system was highlighted. Views and feedback on system design from users can be applied and the system can be configured to meet prescribers' requirement.

"there needs to be clinical input and um clinical expertise involved in designing these systems. And that needs to probably it needs to be for example if there's IT people involved and clinical people" **Junior 1**

It was recommended if that E-prescribing system can be incorporated into electronic health record (EHR) systems. This include patient information such as laboratory results and X-ray.

"It would be good if even on PICS like x-ray there was a tab and x-rays just came into that tab." **Junior 1**

It was suggested that the system in use should be continuously being updated and adapted in response to the change to the new medical knowledge and guidelines.

"to be able to adjust and improve and update the system to keep up with, what's going on in the clinical environment." **Senior 3**

"it needs a constant team of people who are able to readjust, reconfigure prescriptions, manipulate things so that they meet the needs of the clinical environment for that patient, for the team who are using the system constantly." **Senior 3**

4.4 DISCUSSION

4.4.1 Part 1 Key findings

The present study found that the causes and contributing factors to electronic prescribing errors are multifactorial and interconnecting. They are classified into six high-level categories (the computer system, the prescriber, the patient, the task, the team, and the work environment) that contributed to prescribing errors. The causes and contributing factors of electronic prescribing errors reported from different prescribers (medical and non-medical) were similar to prescribing errors that occur with conventional handwritten prescribing (Dornan et al., 2009, Lewis et al., 2014, Ryan et al., 2014) with the exception of errors related to electronic system specifically.

Many factors were identified that are specifically related to electronic prescribing systems encountered in inpatient settings. Prescribers in the present study attributed some errors to the use of drop-down menus during prescribing. The selection errors associated with different types of menu lists such as (drug name, dosage forms, route, etc) was found one of the contributing errors as well. Other system design issues identified is unintended mouse wheeling causing the information selected can also affect the use of drop-down lists and auto-population of information. Therefore, it is important to consider must be such features when designing an electronic prescribing system to prevent errors.

The field auto-population feature appears to pay a contributory factor to e-prescription errors as some prescribers fail to alter any default prescriptions with pre-set forms, dosages or timings already inputted into the system. For example, the e-prescribing populates the common dosage of a required medication. This could mean that dosing errors could occur when the prescriber chooses to change the intended dosage to be given to a patient from the already auto-populated dosage leading to wrong e-prescriptions being generated.

Human factors and system interaction factors were also reported as causes of prescribing errors. Users reported that the system could be non-intuitive when prescribing. Inflexible or complex ordering processes made prescribing particularly difficult and users noted this could result in forced errors. Also, distracting features of electronic systems caused by excessive alerts generated by the system during prescribing were cited as a disruptive effect by prescribers.

Knowledge-based errors, especially about drugs, including indications and contraindications, appropriate doses, maximum dosages, routes, and drug-drug interactions, were described as a

common cause of prescribing errors. Lack of knowledge of medication appears to be a major contributor to prescribing errors (Dornan et al., 2009). Insufficient training received by the prescribers that enable them to use the system properly when they begin work as is widely recognised as an important factor in prescribing errors. Hospitals with electronic prescribing system in use should maintain fully comprehensive training sessions to ensure that everybody has access to adequate training before start using the system. For system development and support; technical, clinical and training responsibilities are usually combined to allow trainers to identify and appropriately respond to varying needs and concerns raised during training activities.

Findings from this study suggest that the framework for analysing risk and safety (Vincent et al., 1998) can be used to identify the causes of prescribing errors. The framework provides a broader understanding of accident causation. The framework includes many features that are of particular importance in hospital practice, such as prescriber, patient characteristics, team working, and work environment factors. In the present study, lack of knowledge and skills and work environment factors were most commonly reported. Attentional slips, memory lapses and lack of knowledge and skills occurred when staff were busy, distracted or tired. Being busy, having a high caseload, having to rush, feeling tired, having difficulty concentrating, multi-tasking, and feeling flustered all made it hard for respondents to apply knowledge they already had. Errors can occur when prescribers are working after hours or on long shifts or dealing with patients who are unfamiliar or had complex conditions. Latent failures provide the conditions in which unsafe acts occur such as high work load pressure and working environment.

Further problems related to the medical profession hierarchical culture results in poor communication between team members and in the follow through of orders given which have been suggested to contribute to prescribing errors. These errors were mainly due to barriers in communication between junior and senior staff members and inability to access insufficient drug information and guidelines at the time of prescription order. Time and job load pressures can lead to prescribers not double-checking information they have been given or clarify or questioning more senior prescribers' orders. A culture where junior prescribers are supported and working as part of a team with more senior staff who can give adequate support and encourage junior prescribers to review prescriptions will greatly improve e-prescribing errors. Poor communication within and between teams can disrupt such improvements in prescribing errors.

The present study showed that inadequate accessing medication history of patient across health care levels leads to prescribing errors. The process of admission to and arrival at the hospital seems particularly to facilitate such errors. The lack of information from primary care about patients' medication was cited as a factor contributing to error in the interviews.

4.4.2 Implication of finding part 1

It is recognised that using an electronic prescribing system reduces prescribing errors, however, it can create or propagate new ones which have been highlighted in previous studies (Ash et al., 2004, Bobb et al., 2004, Koppel et al., 2005, Oren et al., 2003). These errors arise from design interface problems can also occur errors due to lists which are dense and can cause juxtaposition problems. The recognition of such problems and their consequences by system designers will cause reflection when implementing new alerts in e-prescribing systems. These issues need to be addressed by system designers and drug database manufacturers to aid a reduction in risks associated with prescribers making mistakes when using pick-lists and increasing alerts to draw prescribers' attention to possible errors. Also, although most prescribers reported accepting the majority of default doses, they were a contribution factors of dosing to errors, particularly with lack of knowledge. Issues surrounding over reliance on default suggestion electronic prescribing and the potential for error emerged as an important area for further investigation.

The findings of this study indicate that prescribing errors are multifactorial. Organizational factors—such as communication, training, teamwork, interruption and staffing levels have an important influence on prescribing errors. This is consistent with a previous studies (Coombes et al., 2008, Dean et al., 2002a, Dornan et al., 2009, Ross et al., 2012, Ryan et al., 2014). Hospital wards can be busy, noisy working environments. Staff are subjected to repeated interruptions while doing important tasks such as prescribing, despite the knowledge that safe prescribing requires the concentration and attention of the prescribers. The working environment must be addressed to improve prescribing safety.

Obtaining accurate medication history of patients upon admission is vital to reduce prescribing errors. It is important to share and transfer patients' medication histories between primary and secondary care. Franklin et al. (2011) found that lack of information of patients'' medication histories from primary care settings contributed to prescribing errors in hospital settings

(Franklin et al., 2011). Therefore, longer term strategies include developing a national wide electronic information system between primary and secondary care to reduce prescribing errors. Pharmacists can play a vital role in obtaining better medication histories than many physicians and identify more medication doses and frequencies. In a study carried out by Carter and co-workers results showed significant improvements in medication histories and documentation of allergies by pharmacists in Emergency Departments compared with physicians and nurses (Carter et al., 2006).

Lack of knowledge is one of the main causes of prescribing errors, therefore, ongoing education with respect to therapeutics and safe prescribing for the prescribers is necessary. To prevent errors from occurring, it is recommended continuing professional education for safe prescribing practice. In 2010, NHS Health Education West Midlands, University of Birmingham and OCB Media in the UK developed an eLearning programme tool called SCRIPT (Standard Computerised Revalidation Instrument for Prescribing and Therapeutics) to promote safer prescribing (https://www.safeprescriber.org). It is a comprehensive learning tool designed to promote safe and effective prescribing among medical and non-medical prescribers. It is also an important need to ensure that all prescribers receive a comprehensive training on the electronic prescribing system before they use it and be able to make best use of the existing features of their clinical computer systems.

4.4.3 Part 2 key Findings

This study findings describe perceptions of medical and non-medical prescribers when using a home-grown, electronic health care records based, e-prescribing system in an inpatient setting. In this study, it was found most prescriber respondents had positive attitudes towards the potential benefits of electronic prescribing system. Most of prescribers (87%, 20/23) believed that electronic prescribing system can improve prescribing practice by generating more accurate and complete prescriptions. The majority of prescribers considered electronic prescribing system as safer compared to handwritten prescriptions; an opinion supported by quantitative research (Donyai et al., 2008, Franklin et al., 2007, Pizzi et al., 2005). Additional benefits reported by the prescriber respondents of the electronic prescribing system were improved patient safety and reduction of prescribing errors. These findings are in line with the results of previous studies (Ammenwerth et al., 2008, Donyai et al., 2008, Franklin et al., 2007, van Rosse et al., 2009). The EPS can potentially reduce errors and improve patient safety by

eliminating illegible prescriptions and generating real-time alerts for drug-drug interactions, and also reduce dosing errors and duplicate prescribing. An additional benefit of electronic prescribing reported by prescribers was that the system can be used as a virtual passive learning tool as it has a knowledge base as well as real time warning messages. Maxwell and Mucklow (2012) stated that as hospitals move toward electronic prescribing it will make it easy for follow learners to move from educational to clinical environment (Maxwell and Mucklow, 2012).

Although the prescribers in this study appreciated the electronic prescribing, some concerns were revealed by them. These include: overreliance on the system could deskill the prescribers, unfavourable workflow issues and communication pattern which would less time to spent with patients and arising of new kinds of errors associated with such system. Also, prescribers expressed their concerns with interruptive and irrelevant alerts that would lead to alert fatigue. These findings were reported in literature (Abdel-Qader et al., 2010, Jung et al., 2013). Also, lack of training was identified as one major concern associated with using electronic prescribing system. Several staff described learning new skills or achieving optimal system use after "playing around" or advice from other Colleagues. Therefore, formal and continued training would maximise the benefits for both health care organisation and users. Also, updating training to reflect any new system changes is recommended. Training should be aimed towards educating prescribers about the challenges and pitfalls of electronic systems. Studies did include education and training as a solution to some of "the issues" encountered with such systems. Sittig and colleagues made specific recommendations, such as, providing adequate training opportunities for all clinicians to experience the system prior to authorise to login to the live system and enter an order, potentially enforcing a minimum level of training before clinicians are authorized to use the system (Sittig et al., 2008). Training approaches should encompass both procedural tasks (e.g., prescribing a medicine) and cognitive tasks (e.g., interpreting a CDS alert) so that prescribers may realize the full potential of the system.

Participants demonstrated that specific features of the system design, (such as screen size, drop-down menus, screen display, risk factor and medication search field) may contribute prescribing errors. Understanding such issues on system design can be used as a framework design to understand the potential flaws of current EPS design that may affect prescribing process. For further improvement on the system, a number of recommendations were made by respondents. Each recommendation about the system might have a positive effect on reducing prescribing errors as well as patient safety. The recommendations should aid EPSs developers to prioritise their development efforts to meet end users need. Applying human factor

engineering approach to an electronic prescribing system to identify system flaws and error prone in order to make the system more efficient and safer (Beuscart-Zéphir et al., 2010, Niès and Pelayo, 2010). There is little research or evidence on how the interface design of a software can affect usability and patient safety, however, some research has begun in this field (Australian Commission on Safety and Quality in Health Care, 2016, National Patient Safety Agency, 2010).

Currently there is poor communication and sharing data across the primary/secondary care, with many examples of errors arising. In a qualitative study carried out by Franklin and co-workers, found that lack of data about patients' medication histories from primary care is a major cause of prescribing errors in secondary care settings (Franklin et al., 2011). To improve such issue, prescribers recommended if the system could be integrated or linked with primary care systems at national level. This will have the potential to significantly improve communication and share reliable information faster and more easily between acute trusts and primary care practices. Consequently, this will improve the safety and quality of patient care. This would enable prescribers in the secondary care settings to access and review patient's condition and current and previous medication history. This would benefits prescribers also to obtain an accurate medication history and reduce error. The results are in keeping with barriers and potential solutions identified to medication management at transitions of care (Care Quality Commission, 2009).

Prescribers assumed that introducing clinical decision support would be the main patient safety benefit. The positive value of such system is to aid prescribers in their prescribing decision-making process has been acknowledged by them. Improvements in the safety, quality and cost effectiveness of prescribing are expectations when a sophisticated decision support system is in use (Kaushal et al., 2003). The study results are in line with other studies that found that prescribers hold positive attitudes towards the potential benefits brought by clinical decision support (Jung et al., 2013).

The prescribers stated that the alerts should be prioritised based on their clinical significance to avoid possible overload unnecessary alerts that may lead to alert fatigue. This is supported by other studies (Jung et al., 2013, Riedmann et al., 2011a, Riedmann et al., 2011b). The prescribers expressed their need to customise alerts feature to be presented into non-interruptive manners which was suggested by other researchers as well (Borbolla et al., 2010, Oertle, 2012).

4.4.4 Implication of the finding part 2

The results of this study have several implications on stakeholders and prescribers. System designers of either home grown or commercial ones need to pay attention of the safety limitation of the systems by focusing on causes of electronic prescribing errors that are related to the system design and address them by configuring the systems. Also, adopters need to devote attention to improving prescribers by comprehensive and continuous training. In the case of system upgrade, special attention needs to be applied by increasing the level of awareness of end users and making them involved in the upgrade itself by training and educating them. Also, hospitals need to encourage their staff to closely monitor the systems to identify any safety threat of the system or any concerns on system design that may threat patient safety in the early stages as possible.

Socio-technical issue in designing electronic prescribing systems has not been addressed and attention needs to be paid for. Designing electronic prescribing systems needs input from clinicians and other health care professionals as they are key success factors in deploying EPSs. Clinicians should reflect on the optimal system design, layout and optimal clinical information needs in order to design a system that matches their preference and go along with their work flow. Clinicians needs to be involved in the early phases of the development, design and deployment of electronic prescribing systems. Their recommendations need to be incorporated with the total design strategy in order to maximize acceptance and adoption of such systems.

There are two new areas of interest that arose during this study relating to the effect of e-prescribing on real world intentions. Firstly, using electronic prescribing systems has affected the communication patterns between healthcare professionals. Inadequate or miscommunication between healthcare professionals owing to sociotechnical changes. Understanding these changes in patterns of communication between health care team members are important as poor communication threatens patient care and may be one of the major causes of prescribing errors (Westbrook and Ampt, 2009).

Secondly, new technology of electronic prescribing systems encourage prescribers to prescribe remotely. As one prescriber reported it as a concern *"…allow doctors to potentially prescribe medications or fluids for patients without seeing them. Although they're convenient, it can be dangerous because you can just be treating the patient as a name on the screen"*. Such practice would eventually lead to less time spent on exploring patient issues and ensuring

appropriateness of the medication being prescribed. As a result, electronic prescribing systems may introduce new risks to patient safety.

There is a need to integrate electronic prescribing systems within and across organisations and make tailored to an NHS context. It is needed to establish a unified electronic system across the country and make it integrated to primary care settings. Electronic medical record within the electronic prescribing system needs to be unified nationally. This will enable prescribing in any health organisation with the ability to access any information related to patient across health care settings. This will allow sharing and transfer of accurate information within and between health care organisations. However, the feasibility of such recommendation is questionable.

4.4.5 Strengths and limitations of the research

This is the first qualitative study to explore the causes of prescribing errors made by different grades of medical as well as non-medical prescribers in an electronic system setting, with interviewees from different professions, specialities, and levels of seniority. The previous research conducted mainly focus on prescribing by junior doctors and trainees (Dornan et al., 2009, Ryan et al., 2014). The strength of the study is that it provided insights into identified literature gap in relation to medical and non-medical prescriber's perspectives of electronic prescribing systems in hospital settings. This would not have surfaced without in-depth semi structure interview qualitative research. This type of methodology provides a different type of validation and strengthened the confidence in the findings. Also, feedback on system design to promote an ideal system received limited attention because previous research has focused on both: the EPSs role in error reduction and seldom its role in error facilitation. Reliability of this study was achieved by proper study design, achieving data saturation and rigorous approach to data analysis to ensure accurate representation of users' perceptions.

There are several limitations to this study that should be acknowledged. First, the present study was carried out in one hospital site and hence one system was examined. This could limit the generalisability of the findings to other settings as different trusts may have different prescribing practices. Second, according to the study design, qualitative approach was applied by interviewing the prescribers to obtain information regarding the causes of electronic prescribing errors, however, the information gathered on the reasons for errors mentioned are

based on the perceptions of prescribers use of e-prescribing. Since, the interviewees were not necessarily involved in prescribing errors. On the other hand, while any qualitative study by its nature is considered non-generalisable, this present study is likely to reflect similar situations in electronic prescribing systems elsewhere and the themes found are reflected in the extensive literature.

4.4.6 Recommendations and future research

This research has identified number of recommendations to improve patient safety by reducing prescribing errors. The recommendations are:

- Promoting safe clinical working environments creating to be non-interruptive environments by avoiding any from interference from health care professional during prescribing. This can be achieved by designing a specified area within the ward to be used as a prescribing room.
- Compulsory condensed technical training on how to use the system effectively.
- Prescribers can attend continuous education strategies in the form of seminars or lectures to foster their prescribing skills.
- There is a need to improve the way the health care professional communicate with each other in the wards and hand over patients to improve patient safety
- When designing any electronic prescribing system there is a need to consider prescribers views in the design of electronic prescribing system.
- A national wide system needs to be implemented which connect primary health care with the secondary care which will enable to transfer patient medication history different settings.
- Sociotechnical changes to professional communications and patient communications can be improved and clinical services managers must monitor the outcomes.

Future research can be done on comparing two systems one with end-users suggestions on system design and one without on the incidence of prescribing errors.

4.5 Conclusion

This the first study to examine the views of medical and non-medical prescribers and their experience of prescribing errors made by using an electronic prescribing system. The causes of electronic prescribing errors are multifactorial in nature and interconnected. It is usual for a prescribing error to have more than one contributing factor and these may interact to create the conditions for the error. This complex nature of the causes of prescribing error mean that addressing one factor, such as system design, may only result in a limited improvement. Therefore, interventions should focus on training on both pharmacological and safe prescribing practice, as well as technical training on using the current system. The present work builds on previous research on how the system design can affect safe prescribing and have negative unintended safety consequences. These concerns arise in both medical and non-medical prescribers equally. Consequently, applying users' recommendations could guide both stakeholders and organisations on essential system design modifications in order to maximise safety.

As well as e-prescribing safety issues, this qualitative work has uncovered some socio-technical concerns about the effect of technology sociotechnical dimensions. These are: deskilling the prescriber; alert fatigue; less time spent with patients; and lack of enough training. These concerns emphasise to enhance understanding of the societal technical issues need to be addressed when designing a new electronic system on how a clinical service operates with it.

5 General Discussion and Conclusion

5.1 General Discussion

This chapter will both discuss and summarise the main findings of the thesis, addressing the research questions and aims of the study, the results will conclude with recommendations for policy, practice and for future research.

This thesis aimed to examine electronic prescribing systems in secondary care settings by a systematic review and meta-analysis to examine the evidence of the impact of electronic prescribing systems on incidence of prescribing errors in hospitals. This was followed by a quantitative analysis of pharmacist interventions in a well-established multi-professional electronic prescribing system, with a focus on prescribing errors. Finally, a qualitative study was carried out to gain more understanding of the causes and contributing factors of electronic prescribing errors in an inpatient hospital setting. This was conducted through semi-structured interviews with junior and senior medical staff, and non-medical prescribers, using critical incident technique.

5.2 The principal findings from the present study

5.2.1 Systematic Review of Electronic Prescribing Systems

Electronic prescribing systems were found to reduce prescribing errors by 75% compared to conventional handwritten prescribing. The implementation of electronic prescribing systems have not only improved legibility, but also provided enormous potential capabilities for reducing prescribing errors and promoting patient safety. Also, in conjunction with other factors, it improves the clarity of clinical communications, easy accessibility to shared health records, and promoting easy access to care, minimising dependency on human memory and promoting evidence-based prescribing. The marked reduction in prescribing error rates noted following the implementation of electronic prescribing systems is not surprising. The standardised automated format and structure of electronic orders provide an internal exclusion pathway to some error types, such as legibility errors.

However, a major challenge is the requirement for appropriate care which is evidence-based. This is where the implementation of comprehensive electronic prescribing systems applications

which include sophisticated CDSSs are expected to have the highest impact on errors and adverse outcomes.

Studies in the systematic review had substantial heterogeneity even with subgroup analysis, reflecting the variety of electronic prescribing systems and their uses. There appear to be no difference in relative risk reduction of prescribing errors with electronic prescribing systems with advanced clinical decision support in comparison to those with limited or no decision support, although Ammenwerth et al. (2008) had previously suggested the reduction of errors is dependent on the degree to which decision tools are incorporated within the system. Therefore, there is requirement for more evidence to support these findings. Based on the type of electronic prescribing system used, any of these prescribing functions may to varying extent be supported by the technology. Others have argued the taxonomy of "basic" versus "advanced" CDSS shows that electronic prescribing systems with advanced CDSS have a significant relative risk reduction compared to those with limited or no decision support (Schedlbauer et al., 2009, Shiffman et al., 1999). Further studies, with more advanced CDSS, may lead to more evidence of benefit, that this thesis' systematic review did not find.

In addition to identifying a marked overall reduction in medication-prescribing error rates post electronic prescribing systems implementation, the systematic review chapter also found substantially different baseline prescribing error rates, which ranged between 0.1% and 94.2%, whereas post-system implantation error rates ranged between 0% and 24.4%. These variation in error rates may be due to inherent differences between study settings. However, the likely causes to these variations between studies may be attributed to the differences in definitions of an error and methods used for error detection.

Few studies, for example, reported that missing weight or no signature can be an error of omission while some included rule violations, however, other studies excluded these elements in their lists of error definitions. Therefore, it is important for future studies to utilise a more standardized set of criteria when defining and reporting prescribing errors. Reckman et al., (2009) argued that there is a need to include a clear definition of prescribing errors in future studies; absolute error rates pre- and post-electronic prescribing system; a suitable denominator, such as the total number of medication orders; quantifying of errors categorised based on a standardised severity scale; and appropriate significance testing. Such information would facilitate to compare between studies more accurately.

The quality of included studies and its reporting patterns were not always adequate and needs to be taken into consideration when interpreting the results of the studies. Efforts to improve the study designs, reporting quality and analyses of evaluation studies are needed, as well as clarity on prescribing errors definitions used.

National Health Service Connecting for Health (NHS CFH) was created for implementing and developing the NHS national information technology programme. One of the proposed initiatives was the implementation of an electronic prescribing system, which aimed to minimise the risk of iatrogenic harm and consequently improve patient safety (Car et al., 2008), owing to its in-built functionalities such as knowledge base and decision support, alerts for drug interaction, allergic reactions and drug contraindication, formulary guidance or management. Although, the project ultimately failed to deliver on electronic prescribing, the core concepts of the project were adopted by NHS Digital, formerly known the Health and Social Care Information Centre (HSCIC), in 2013. It provides national data and information technology digital solutions for NHS and social care (NHS Digital, 2018).

In summary, the present systematic review found that electronic prescribing systems reduced prescribing errors by 75% compared to conventional handwritten prescribing. It provides an evidence that the use of electronic prescribing systems generally are effective tools for reducing the risk of prescribing errors in hospitalised patients, thus intuitively improving patient safety.

5.2.2 Pharmacist Interventions Study

The pharmacist intervention study examined electronic review notes sent to prescribers by pharmacists. It was found that pharmacists identified and rectified a prescribing error in 1.1% of all medication orders entered electronically by prescribers during the study period as part of the routine hospital pharmacy service. This rate is almost half that of a previous study that found a low rate 2% of electronic medication orders had an error (van Doormaal et al., 2009b). Other studies (Abdel-Qader et al., 2010, Donyai et al., 2008) have found that prescribing errors rates 2% and 8.4% respectively, but one case was conducted on a surgical ward (Donyai et al., 2008) and Abdel-Qader and co-workers focused only on discharge medication prescriptions. Reasons for the error rate in this present study being low could be owing to differences in the prescribing practice in hospital, some may be about electronic prescribing system, and some may be due to failure of clinical pharmacists to detect or report errors.

This low prescribing error rate (1.1%) could suggest that the electronic prescribing system is very effective in reducing prescribing errors, in studies of paper based prescribing rates of over 7.5% have been found (Ashcroft et al., 2015, Ryan et al., 2014, Seden et al., 2013), although as already noted the present study was dependent on pharmacists' detection of prescribing errors, and their willingness to report them to prescribers via the electronic intervention system. The interventions of pharmacists on addressing prescribing errors associated with inpatient medication orders were timely, efficient and equitable which consequently reducing the likelihood of harm to hospitalised patients. Assuming the pharmacists' interventions were acted upon, there is a potentially large effect on preventing patient harm. However, the present study was unable to ascertain if the pharmacists' interventions had been acted on.

Despite low rate of prescribing errors, electronic prescribing systems showed new patterns of error such as data entry errors, many of them which would could be predicted from Reason's human error model (Reason, 1995). For example, errors were observed when prescribers were made to select from an alphabetical ordered dropdown list. This was a form of "slip" in Reason's model. An example of a drop down list error was a case where a clinician prescribed Seretide® (salmetrol and fluticasone, the active ingredient, is used prophylaxis of asthma) instead of Ventolin® (Salbutamol, the active ingredient, used in the treatment of asthma or Chronic Obstructive Pulmonary Disease). Had the error not been intercepted by the pharmacist, this error would have reached the patient and could have caused harm. It is therefore important that electronic prescribing systems introduced are closely monitored for newly introduced error types not previously recognised.

Unintended medication omission following an acute hospital admission was identified as the most frequent error. Prescribing during an acute hospital admission may be unavoidable even with a lack of patients' full medication history from primary care. There is evidence that medication history taking by medical staff is poor (De Winter et al., 2010, Tam et al., 2005), and the task of medication history should be allocated to clinical pharmacists to ensure better communications about medication.

Obtaining an accurate and comprehensive medication history at hospital admission is still a major challenge even with the using of electronic prescribing systems. It is key that more current methods are improved to allow better transfer of patients' medication histories between primary and secondary care. Improved methods can include developing an electronic information systems which is common to both primary and secondary care. However, before

these are implemented, patients should be encouraged to carry up-to-date records of the medications. Implementing medication reconciliations as soon as a patient is admitted will reduce omission of long-term medicines at hospital admission. Medicine reconciliations is when an up-to-date and accurate list of medications is created at transitions of care. The information is collected using multiple sources of information including pre-admission medication being checked with currently prescribed medications. Any identified discrepancies need to be communicated to the current care team. Despite, electronic prescribing, still important to include pharmacist role to ensure medication safety at the interface between primary and secondary care.

Unintended medication omission following admission was the most prevalent type of errors observed in the present study. Therefore, ward pharmacists have a main role in medication reconciliation for patients on admission. This would ensure that the medication lists are accurate and complete as soon as possible after admission. Also, involves taking a detail medication history and recording a full list of a patient's medication in the patient's notes, and discussing with clinical team in charge of the patient to ensure all regular medications are prescribed during a patient's admission, if appropriate (Viktil and Blix, 2008). Furthermore, on discharge, pharmacists ensure that necessary regular medications are correctly prescribed, and any new medications started during admission that need to be continued are prescribed accurately prior to discharge. This process carried out by the pharmacist allows for majority of omission errors to be rectified, highlighting the importance of medication reconciliation as soon as a patient is admitted to hospital to minimise essential medication doses being missed. Therefore, the role of pharmacists in acute admission is valuable to patient health.

The pharmacist inventions study showed that dosing errors were common type of errors reported. This could be the case with system, by default, providing usual dose of drugs. Evidence shows that electronic prescribing can cause prescribing errors due to encouraging clinicians to prescribe the usual dose even though, at times, the patient may require a different dose (Koppel et al., 2005). Such dose errors occur due to prescribers accept the default dose given by the electronic prescribing system without taking patients renal function into account. Prescribers should check and change the default CPOE doses if required otherwise, this may lead to prescribing errors.

An electronic prescribing system has been effective against errors related with drug allergies. However, incorrect allergy recording in the system can prevent warnings to prescribers when selecting a drug to which the patient is allergic to.

The incidence of errors detected in surgical specialties was higher in comparison to medical specialties. This could be as a result of the fact that surgical hospitalisations are mainly focused on acute interventions rather that current therapeutic management of co-morbidities of patients. This perhaps highlights the importance of good oversight of prescribing, especially in non-medication related specialities.

In summary, the pharmacist intervention study found that pharmacists have a pivotal role in identifying, rectifying, preventing prescribing errors before they reach and might harm the patients. Pharmacists' role within hospitals need to be expanded to include their integration within medical teams providing collaborative patient care.

5.2.3 Qualitative examination of medical and non-medical prescribers.

The qualitative arm of this thesis has provided further understanding of the factors contributing to electronic prescribing errors from the perspective of medical and non-medical prescribers, and reinforced some of the findings from the examination of pharmacists' interventions. These factors, namely the computer system (e.g. drug picking errors), the individuals (e.g. lack of knowledge), the patients (e.g. patient is unhelpful), the task (e.g. medication history unavailable), the team (e.g. poor communication between staff members), and the working environment (e.g. interruptions and distractions). The complicated nature of the causes of prescribing error mean that addressing one factor may only result in a limited improvement.

Vincent's model was applied to analyse the causes and contributing factors of electronic prescribing errors in hospital settings. The model analyses error producing conditions and organisational factors into a single broad framework of factors affecting clinical practice. According to Vincent's model, prescribing errors occur as a consequence of latent failures (i.e. management decision, organizational processes) that cause conditions of work (e.g. high workload, lack supervision, lack of proper communication, knowledge/skills), which in turn produce active failures. The model has 7 level of system factors that can influence clinical practice and may result in adverse events: (1) institutional context, (2) organizational and management factors, (3) individual factors (4) work environment, (5) team factors, (6) task

factors, and (7) patient factors. Our qualitative work with medical and non-medical prescribers supports Vincent's model framework of factors contributing to patient safety incidents in hospital settings an additional one component which the computer system. An example of individual factors include the lack knowledge and skills which will obviously affect their prescribing. Task factors include availability of protocols and test results which influence the prescribing. Working environment conditions include the physical environment, interruptions and distractions that affect healthcare professional during prescribing.

The findings of the qualitative arm of the thesis, could aid multifaceted interventions being developed and implemented in electronic prescribing systems. Electronic prescribing systems should be designed with the end user in mind, rather than as purely technical systems. Engaging end users participation during systems development is essential for the successful outcomes of health information technology process (Høstgaard et al., 2011).

Lack of prescriber's knowledge about the medication such as dosing or therapeutic knowledge such as comorbidities, were described by most of the prescribers to be the causes of prescribing errors. Increased workload, low-staffing levels, interruptions and distractions during a task, busyness or fatigue with long working hours were attributed to high error rates. Lack or poor communication or miscommunication between healthcare team members were also reported as the most common factors contributing to prescribing errors. This shows the importance of addressing all factors that contribute to error, electronic prescribing is not a panacea for all influences on poor or mistaken prescribing.

The most important finding from the qualitative study chapter that the causes of electronic prescribing errors were multifactorial in nature and interconnected. Electronic prescribing was particular linked to error-producing conditions at the level of technology, prescriber, patient, task, team, and environment. Active failure types included slips due to wrong selection from a drop-down menu and rule-based mistakes due to over-reliance on the default auto populated fields. Some findings correspond with existing literature exploring paper-based settings' error causation, that highlights factors with are unique to electronic prescribing, and suggest error aetiology differences that should be considered when wanting to improve prescribing safety, but human aspects of prescribing also need to be addressed.

An unexpected finding from this study was that electronic prescribing could damage other aspects of the patient-prescriber relationship, or professional communications. Remote prescribing might affect patient-prescriber communication and could lead to an inadequate

assessment of patients case and prone to prescribing errors. One study found that poor communication and co-operation with patients made prescribers susceptible to errors (Emmanuel and Okeke, 2016). Poor communication between health care professionals in the context of handing over patient clinical information was identified as a major risk to patient safety. Handover communication between health professionals has also been found to be unstructured and error prone (Manser and Foster, 2011).

The underlying causes of prescribing errors in hospitals were highlighted in this study, many of which are amenable to intervention, through safer systems for medication prescribing, and improved training. However, some causes like workload and time pressures are more difficult to address. Substantial improvements could be made through managing the range of issues identified by this study to allow for safe prescribing in hospitals.

In summary, electronic prescribing systems in hospital are often thought of as inflexible and complex to clinical responsibilities and local needs serving as a contributing factor to the prescribing errors. Therefore, an electronic prescribing system has to be adaptable for all healthcare staff professional requirements. Actively involving these healthcare staff in the development of its design features including the system and user support interfaces should be a key part of system development and maintenance. Suggestions from some of the interviewees on system design such as drop-down menus, warning massages and pre-constructed order sets, show how valuable insights can be provided. These suggestions are important for the potential evolution of electronic prescribing systems.

5.3 Strengths and limitations of this thesis

A strength of this thesis is that it has provided an overview of electronic prescribing, based on a systematic review of literature, as well as examination of pharmacists' interventions on prescribing errors, as well as a qualitative piece of work examining both medical and non-medical prescribers views on e-prescribing. This allows for cross comparison, to see if similar issues have arisen, and provides some level of robustness of the research. Many similar issues were clearly found across all three research chapters, strengthening the confidence with which their individual findings can be used to implement change.

5.3.1 Systematic Review

Despite the limitations of individual elements of the research, the limitations of systematic review include aspects such as the primary focus on quantitative studies. Qualitative studies are valuable as they assist in understanding findings of quantitative studies; therefore it is vital to include qualitative study findings in any analysis. The systematic review had a broad approach, which was advantageous, but lack of qualitative studies caused it to be arguably less comprehensive than it could have been. However, it was felt that having a qualitative focus provided a more clearly defined area of research to examine systematically. A follow-up separate systematic review of qualitative studies might provide additional insights.

While comprehensive key terms were used to locate studies, some studies may have been indexed under different key terms and therefore may have been omitted. To avoid this, a very comprehensive search strategy was used to locate studies which may be indexed under other key terms, so it is felt this risk was minimised. Non-English literature was excluded, which may have led to good quality non-English language papers being excluded, which could have enriched the evidence base.

A peculiar limitation of systematic reviews is that the reliability of the findings depends on the quality of the included studies. Hence, this study rated the quality of the studies included in this review based on the CASP quality assessment tool criteria. While we noted the majority of studies to be of moderate quality, there were no studies classified as strong. As such, in addition to evaluating the findings from the current evidence base, our study also exposed key areas for robust further studies using larger sample sizes in order to determine the exact effect of the electronic prescribing systems and CDSSs implementation.

5.3.2 Pharmacists Interventions Chapter

In the UK, few studies have examined the relationship between pharmacists' interventions and prescribing errors in the context of an electronic prescribing system However, these studies have flaws, being focussed in one case on a surgical ward and on discharge medication in the other. The present study was intended to investigate prescribing errors detected by clinical pharmacists in an inpatient setting in the context of electronic prescribing system.

There are several limitations associated with the present study. Firstly, the study was conducted in a single teaching hospital, which potentially reduces the general application of the findings to other clinical settings. Data depended on ward based pharmacists volunteering clinical interventions and relied on individual pharmacists identifying, intervening errors, and documenting all problems. Therefore, there might be variability between pharmacists in the numbers and nature of prescribing errors documented, due to differences in experience, motivation, and knowledge. Also, failure either to detect or to record errors would lead to underestimate the actual prescribing error rate in hospital inpatients.

5.3.3 Qualitative examination of prescriber views

This is the first qualitative study to explore the causes of prescribing errors made by different grades of medical as well as non-medical prescribers in an electronic prescribing system. The study provided fresh insights into identified literature gap in relation to medical and non-medical prescriber's perspectives of electronic prescribing systems in hospital settings. Also, feedback on system design to promote an ideal system received limited attention because previous research has focused on both: the electronic prescribing systems role in error reduction and seldom its role in error facilitation. An unexpected finding was the damage to professional communications that electronic prescribing systems appeared to create. Reliability of our study was achieved by proper study design, achieving data saturation and rigorous approach to data analysis to ensure accurate representation of users' perceptions.

There are several limitations to this study that should be acknowledged. First, this study on the causes of electronic prescribing errors was carried out on one hospital site and one system, potentially limiting the generalization of findings to other settings as different trusts may have different procedure prescribers' practice. Second, the interviews were made with prescribers who may not have made errors. However, our study findings are likely to have uncovered some views, concerns and practices which exist in similar UK NHS trusts that operate electronic prescribing systems, since some of the principles of how electronic systems operate are very common. For example, drop down menus and default dosing patterns are widely used features.

5.4 Implication for policy, practice and research

To date, the adoption of prescribing systems in the UK hospitals is only 35% (A Slee, personal communication, 01 May 2018), although there are a growing number of hospitals in the UK who have introduced electronic prescribing systems (Digital Health, 2018). This thesis provides useful information that may help with the implementation of electronic prescribing,

The findings of this thesis contribute to the body of evidence that electronic prescribing systems are effective tool in reducing prescribing errors, as well as providing a deep analysis of the causes and problems associated with electronic prescribing errors in secondary care for both medical and non-medical prescribers. The types, and severity, of prescribing errors documented by hospital pharmacists within an electronic prescribing system, showed their value in identifying and preventing prescribing errors before harm could occur to patients. A number of policy and practice suggestions arise from this, as well as future areas of research.

5.4.1 Policy

A number of policy recommendations arise from this work:

- Although e-prescribing should not, and cannot, completely replicate paper based prescribing systems, ensuring uptake by clinical teams requires incorporation of established working patterns and work flow. System flexibility to fit existing practices can enhance easy accessibility and minimise rigorous training needs.
- Pharmacists are an essential part of the e-prescribing procurement and evaluation team because of their extensive experience in designing and moderating paper-based systems.
- When a new e-prescribing system is implemented, it should allow the local system sponsor to configure software behaviour software (mode of operation). For instance, the extent of decision support given to prescribers, how default instructions or dosing be set (or not), when alerts will be triggered, and how large a time window is acceptable for an ‘on-time’ administration of a medicine.
- Electronic prescribing system should provide standardised templates for data collection, management, and display. These allow the most effective way of harnessing the benefits of electronic prescribing, and prevent user confusion. Examples of a template includes; content of a discharge summary, the definition of order sets, or the

allergy entry screens. Systems should allow adjustments, extensions or reworkings of these templates over time.

- Users can identify new varieties of prescribing error, as shown in this thesis, and in previous studies (Coiera et al., 2006, Magrabi et al., 2010). System designers can use these insights to make design improvements to reduce the risks of mistakes from drop down menus, alert fatigue for contraindicated prescribing, and the need for blood-test monitoring.
- It is also important that prescribers are making using of all available features of their computing systems (for example, by esuring that important information such as drug allergies are accurately coded on the system; by attending to hazard alerts).
- Prescribing errors need to be reported to allow for effectiveness of medication safety officers and safety groups. Hospital executives and managers can promote a safety focus and fair blame culture to improve safety behaviours. Such reports should be used to improve the design of electronic prescribing systems, both locally and more widely.

5.4.2 Practice

Investigated electronic prescribing errors in this section arose from multiple causes. These causes of prescribing errors have been attributed to multiple factors including the prescriber's skill-based or knowledge-based errors, prescriber's lack of experience with using the electronic prescribing system, technical complexity of the e-prescribing system itself, and problems resulting from prescribers' interaction with the system. There seems to be a lack of formal training on using electronic prescribing system and ongoing education in therapeutics and safe prescribing for prescribers with relatively little emphasis on these topics in the vocational training schemes.

The present study suggests that training on therapeutics, safe prescribing and technical training needs more emphasis in prescriber's continuous education. Increasing the length of the training programme sessions would allow more time to address safe, effective prescribing, and medicines management and increase the scope for greater attention to these factors in healthcare professionals continuing professional development. This can be delivered via educational packages that address key safety concerns as well as intensive training on practical prescribing on the system, audits that identify and correct errors, and continually auditing of

significant prescribing events. Also, it would also be valuable to encourage prescribers to focus on improving safety systems in their practices.

The present study highlighted that with high workload, time pressures and associated stress, errors were inevitable, with the main problem being limited time on prescribing tasks which meant that prescribing issues (including prescription review). One possible solution to this would be to work in a team where the tasks and responsibilities are delegated equally. Other options could be to increase staffing, and train more non-medical prescribers, such as pharmacists, who might be better placed to deal with complex medication regimes.

New type of errors have been found following implantation of electronic prescribing systems. These include entering a correct order in the wrong patient's record, failing to change the default dosing, or inappropriate use of decision support. It is difficult to make a clear conclusion about these new error types due to the scarcity of high quality studies which reported error severity. Also, little discussion was found in most papers regarding such challenges, or even how to develop methods to identify such errors associated with electronic prescribing system. New errors should be taken into consideration because they could potentially harm patients if the CDSS does not include sufficient quality assurance and safety measures, or if ePrescribing systems with defects due to poor design does not perform important tasks such as taking into account socio-techno-cultural issues. Also, new prescribing errors may also arise when prescribers pick from a drug list (drop-down menu) or while filling out the free-text fields in an electronic prescription. There are potential capabilities to minimising the size of drop-down lists and free-text prescribing within the system through the building of well-designed, pre-defined ‘order sentences’ into the system.

Participants were satisfied to identify aspects of improved efficiency in comparison to paper, however they were reluctant to spend more time addressing inconveniences such as interpreting confusing interfaces. Such frustrations may pose an introduction of distractions which can lead to attentional failures, or encourage using alternate routes, unsafe practices and negative feelings. Poorly designed interfaces as well as complex prescribing functions have previously been reported (Ash et al., 2007c, Campbell et al., 2006, Koppel et al., 2005, Westbrook et al., 2013a). There is an urgent need for electronic prescribing software designers to meet demands of end users who are working in high-pressured environments by addressing usability issues and revolutionising electronic prescribing interface designs. Therefore, to design and tailor the system to individual needs, a close collaboration between system designers, information

technology staff and clinician needs to be considered. This can be achieved by different groups of end-users continuously testing prototypes and re-designs being made in response to feedback where necessary (Mair et al., 2007).

There should be an active encouragement to achieve a detailed critical feedback from users of new e-prescribing in order to ensure that new applications are fit-for-purpose and minimise safety risks. Prescribers (medical and non-medical) from different specialities will be better positioned to work on the on the electronic prescribing systems developers. This will potential enhancing safety of the systems and maximise the benefit of the systems.

Local solutions to usability problems should be offered by local teams where possible. Minimising non-essential and untimely alerts can help reduce alert fatigue. Nevertheless, a certain level of sophistication is expected by electronic prescribing users to prevent obvious errors. Furthermore, shorter lists have been advocated by typing more letter to reduce wrong selection from drop-down menus.

Hospitals must discourage prescribing away from the patients by providing infrastructure supports bedside prescribing through making multiple portable computers available during ward rounds as these would encourage more efficiency distribution of workload amongst members of the team.

With a drive to improve prescribing education in recent years (Dornan et al., 2009, Ross et al., 2013), future educational strategies should focus on how best prescribers can use electronic prescribing systems. Integrating electronic prescribing systems and electronic patient records into the undergraduate education of healthcare professionals become a requirement. In the UK, a national working group to integrate electronic patient records into undergraduate healthcare curriculum across UK universities has been started (Wilson and Pontefract, 2018). This training program aims to help students to acquire the essentials electronic patient records systems and prescribing medications related knowledge and skills to the prescribing and the safe management of medications. This would allow future healthcare professionals to be prepared to practice safely and competently on initial registration.

This study also raises awareness on the electronic prescribing system limitations, the risk of over-reliance and the need to address new things precipitated by the electronic prescribing that need to be learnt such as choosing diluents for syringe driver.

The technical design of electronic systems is, particularly the user-interface, is commonly considered to play an important part in the behaviour of users adoption of a system, and can lead to significant levels of frustration when they occur (Brown et al., 2016, Cresswell et al., 2014). Equally, the technology design can positively influence user satisfaction and adoption (Redwood et al., 2011, Westbrook et al., 2013b) as this looks at ergonomics or human factors, referred to sociotechnical factor or the way humans and technology interact.

As a result of frustration from usability problems, cases have occurred where users have developed workarounds which were perceived to have adverse effects on patient safety. Therefore, it is recommended for the system designers to pay attention to the different types and needs of user groups (for example, experienced/inexperienced users and different professional groups). Also, to improve usability and avoid frustrations, it is recommended for a system to be tested with users to identify issues (Miranda et al., 2001).

5.4.3 Research

The study design, examining pharmacist interventions and user experience of e-prescribing, developed for this project could be applied to future research to evaluate e-prescribing systems. Consulting a range of users to identify and contribute to evidence based usability standards should be an important aspect of e-prescribing research.

Healthcare technology related studies are often complicated, and e-prescribing systems are not an exception. Evaluations of an electronic prescribing system post implementation need to pay attention to organisational learning processes with the main emphasis on the learning curve (van Rosse et al., 2009). Longer-term evaluations are also required in order to assess the long term impact of such systems (Wolfstadt et al., 2008). Such evaluations may benefit from framing in the context of human error theory, such as Reason's model of human error, since many of these human errors can be provoked by poor design or implementation of e-prescribing.

The major limitations of previous research outputs were that studies did not provide sufficient information in order to assess in detail the comparability of the intervention and comparison groups (e.g., by failing to report baseline characteristics or training session given to prescribers

prior to launching the system). These created difficulties in analysing whether the differences found between the study groups truly originated from electronic prescribing, or from other factors. Also, the study designs used have an effect on the results observed; they are based on little evidence before and after study designs. Hence, making it very unclear whether any context such as staffing or workflow of the study departments would have changed over time, hence influencing the observed effects. Also, for non-random allocations of patients and clinicians to study groups which affects the validity of the analysed studies. These issues need to be dealt with in details in future studies by providing a full description of individual study details, to enable quality assessment.

5.5 Future work

Further research is required on the impact of electronic prescribing systems on the incidence of prescribing errors. Randomised controlled trials are the gold standard for the evaluating of electronic prescribing system, however, they are not feasible in the context of hospital settings. Therefore, an alternative robust study design such as time-series based designs with a preferable contemporaneous control groups should be considered instead.

There is need for further research in future, into the design features, knowledge-bases and, clinical relevance of output, interoperability of electronic prescribing systems and socio-technical factors that improves usability. This research needs to be done on electronic prescribing systems whether in-house systems or commercial off the shelf solutions.

To determine how participants viewed the screen and worked through the scenarios, a supplementary qualitative study using think-aloud methods (where a user verbally expresses their thoughts and decisions as they use the system to researchers), follow-up interviews, and/or focus group of participants can be used. This would look into the above factors influenced their uptake and understanding of information using the screen and to determine what impact this may have had on their prescribing behaviour, for example prescription selection. This mixed methods approach would provide a better depth of understanding on how the prescribing decision made is affected by the user interface design features.

More research into how information available during prescribing such as lab results and decision support will contribute additional evidence on the e-prescribing system's user interface key features that will aid prescribing. As a whole, a broader scale investigation into

the potential value of e-prescribing systems is needed to determine its benefits and the most appropriate way to use it. The success or failure of e-prescribing systems needs to be thoroughly evaluated to set the ground for more complex study designs that will evaluate their effectiveness based on patient safety and other patient-important outcomes.

A novel finding from the qualitative arm of this study, was the potential for electronic prescribing systems to impact to reduce human relationship among prescribers, other professional colleagues, and patients which is vital for patient care. Communication issues arise from using electronic prescribing could have an impact on patient safety in hospitals, including reducing the safety of prescribing decisions and shared decision making. Therefore, further research should be conducted on the effect of electronic prescribing systems on patient contact and inter-professional relationships.

5.6 Conclusion

The findings from this research project contribute to the evidence currently available on the impact of electronic prescribing system on the incidence of errors. The systematic review demonstrated that electronic prescribing systems generally are effective tools for reducing the risk of prescribing errors in hospitalised patients, thus improving patient safety. Implementing an electronic prescribing system was associated with a greater than 75% decline in prescribing error rates in hospital-related settings. This review found that there is no difference between commercial and home grown systems, with or without clinical decision support. Importantly, a lack of standardised definition and severity scales for prescribing errors was also encountered.

Examination of a pharmacist's clinical intervention system found that prescribing errors still occur even when using electronic prescribing systems, including ones judged significant. Pharmacists have a vital role in identifying and preventing prescribing errors before they might harm patients. Pharmacists' role within hospitals need to be expanded to include their integration within medical teams providing collaborative patient care, and pharmacists are certainly still required post e-prescribing implementation. Prescribing errors occur most frequently on admission compared to other stages during hospitalisation. The present study also identified that the current method of transferring and sharing patients' data between primary and secondary care is a key area of error.

Qualitative examination of e-prescribing user experiences found that the causes of prescribing errors are multifactorial in nature and interconnected. Moreover, the complicated nature of the causes of prescribing error mean that addressing one factor may only result in a limited improvement. Therefore, prescribers could benefit from training on both pharmacological and safe prescribing practice as well as technical training on using the current system. The present work builds on previous research on how the system design can affect safe prescribing and have negative unintended safety consequences. Users' recommendations should guide both stakeholders and organisations on system design, and subsequent development of systems, in order to maximise safety. Additional to this, socio-technical issues related to e-prescribing apparent, with changes to inter-professional and patient communication. Gains in safety from e-prescribing, should not be at the expense of reduced patient-professional communication.

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Appendices

Appendix 1

Search strategy details

Database: Ovid MEDLINE(R) <1946 to April Week 3 2016>
Search Strategy:
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1 exp Medical Order Entry Systems/ or exp Pharmacists/ or exp Drug Prescriptions/ or exp Hospitals, Teaching/ or exp Medication Errors/ or exp Electronic Prescribing/ or exp Pharmacy Service, Hospital/ or exp Medical Staff, Hospital/ (113606)
2 exp Nursing Staff, Hospital/ (39045)
3 exp Drug Prescriptions/ or prescribing mistakes.mp. or exp Medical Order Entry Systems/ (27163)
4 preventable adverse event*.mp. (177)
5 near miss.mp. (853)
6 prescription error*.mp. (236)
7 1 or 2 or 3 or 4 or 5 or 6 (149145)
8 exp Pharmacists/ or exp Drug Prescriptions/ or medical prescribers*.mp. (36079)
9 exp Drug Prescriptions/ or exp Pharmacists/ or non medical prescriber*.mp. or exp Nurses/ (107450)
10 exp Pharmacists/ or independent prescriber*.mp. or exp Nurse's Role/ (45589)
11 non medical prescriber*.mp. (31)
12 exp Drug Prescriptions/ or exp Pharmacists/ or non medical prescriber*.mp. or exp Nurses/ (107450)
13 8 or 9 or 10 or 11 or 12 (134524)
14 7 and 13 (42979)
15 hospitali#ation.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (138189)
16 hospital*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (1093720)
17 (secondary care or hospital).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (853274)
18 15 or 16 or 17 (1095771)
19 14 and 18 (14122)
20 electronic prescribing.mp. or exp Electronic Prescribing/ or exp Clinical Pharmacy Information Systems/ (1857)
21 19 and 20 (223)
22 dispensing error*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (193)
23 administration errors*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (358)
24 22 or 23 (532)
25 21 not 24 (217)
26 (case reports or comment or congresses or editorial or historical article or interview or letter or news).pt. (3412294)
27 25 not 26 (204)

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Appendix 2

Quality assessment tool questions

Overview of the study

- Did the study address a clearly focused issue?
- Was the method of participant allocation appropriate?
- Was the control group unaffected by the intervention?

Validity of the result

- How precise the results?
- Were the participants in the intervention group similar to those in control?
- Were the measurement outcomes carried out in the same ways in both groups?
- What was the effect of E-prescribing system on the incidence of prescribing errors?

Applicability

- Are the results generalizable to a different sitting?
- Were all outcomes considered?
- Are you able to assess the benefit versus the cost or harm?

Appendix 3

Table 6.1: Quality scoring assessment of studies

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total
Ali et al. (2010)	2	0	2	1	0	2	1	1	1	1	11
Armade et al. (2014)	2	2	2	2	2	2	2	0	2	2	18
Barber et al. (2006)	1	1	2	1	0	2	1	0	2	2	12
Bates et al. (1998)	2	2	2	2	0	2	2	0	2	2	16
Bates et al (1999)	2	2	2	2	0	2	2	0	2	2	16
Choo et al. (2014)	1	1	2	1	0	1	1	0	1	1	9
Collin and Elsaid (2011)	2	1	2	2	0	2	2	0	2	2	15
Colparet et al. (2006)	2	1	2	2	2	2	2	0	2	2	17
Cordero et al. (2004)	2	1	2	0	1	2	0	0	2	2	12
Delgado et al. (2007)	1	1	2	0	0	1	2	0	2	2	11
Donyai et al. (2007)	1	1	2	2	0	2	2	0	2	2	14
Evans et al. (1998)	1	1	2	0	0	2	2	0	2	1	11
Fontan et al. (2003)	1	1	2	2	0	2	2	0	2	2	14
Franklin et al. (2007)	1	1	2	0	0	2	2	1	2	2	13
Holdsworth et al. (2006)	2	1	2	2	1	2	2	0	1	2	15
Jani et al. (2010)	1	1	2	2	0	2	2	0	2	2	14
Jozefczyk et al. (2013)	0	0	1	1	0	2	1	0	2	1	9
Kadmon et al. (2009)	1	1	2	2	0	2	2	0	2	2	14
Kazemi et al. (2011)	2	1	2	2	1	2	2	0	2	2	16
Kim et al. (2006)	1	1	2	2	0	2	2	0	1	1	12
King et al. (2003)	2	0	2	2	0	2	2	0	2	1	13
Mahonney et al. (2007)	1	0	1	1	0	2	2	0	1	1	9
Menedez et al. (2012)	1	1	2	2	0	1	2	0	1	2	12
Oliven et al. (2005)	1	1	1	2	1	2	2	1	2	2	15
Potts et al. (2004)	2	1	2	2	1	2	2	0	2	2	16
Redley et al. (2012)	1	1	2	1	0	2	1	0	1	1	10
Shawahna et al. (2011)	1	1	2	1	0	2	2	0	2	2	13

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total
Shulman et al. (2005)	1	1	2	2	0	2	2	0	2	2	14
Spencer et al. (2005)	1	0	1	2	0	2	2	0	2	2	12
Van Doormal et al. (2009)	2	0	2	2	1	2	2	0	2	2	15
Velez et al. (2011)	1	0	1	2	0	2	2	0	2	2	12
Voeffary et al. (2006)	1	1	1	1	0	2	1	0	2	2	11
Walsh et al. (2008)	1	1	2	2	1	2	2	0	2	1	14
Warrick et al. (2011)	0	0	1	2	0	2	2	0	2	2	11
Weant et al. (2007)	1	0	1	1	0	2	1	0	2	1	9
Went et al. (2010)	1	0	2	1	0	2	1	0	2	2	11
Westbrook et al. (2012)	1	2	2	2	1	2	2	1	2	2	17
Wetterneck et al. (2011)	1	1	2	2	0	2	2	0	2	2	14