THE IMPACT OF THE DIABETES INPATIENT CARE AND EDUCATION (DICE) PROJECT ON PATIENT CARE OUTCOMES

by

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ABSTRACT

Diabetes is a common disease with an increasing prevalence, however its management in the hospital setting is often a secondary concern with poorer outcomes in this group. The aims of this research were to 1) explore the impact of a nurse delivered whole systems approach, the Diabetes Inpatient Care and Education (DICE) project on diabetes inpatient care, examining the role of diabetes inpatient specialist nurses in the current health service, (2) examine the impact of diabetes and hyperglycaemia in patients attending for orthopaedic surgery and develop guidance for optimising care for these patients on this pathway; (3) explore the barriers and facilitators for staff in the implementation of a diabetes empowerment tool in the surgical pathway.

The description, development and delivery of the DICE project are outlined in Chapter 1. In Chapter 2 the impact of the DICE project on length of stay, mortality and readmissions is examined using both before and after measurements and the quasi-experimental technique of interrupted time series analysis. A systematic review exploring the existing literature on the impact of diabetes inpatient nurses on patient care comprises Chapter 3, and Chapter 4 goes on to address some of the gaps highlighted in the systematic review by examining the impact of the DICE project on in-hospital complications and patient harms.

Chapter 5 provides a review of the evidence for diabetes and hyperglycaemia in orthopaedic surgery, examining each stage of the perioperative pathway. It goes further to describe guidance for optimising care for patients along the pathway. Chapter 6 explores the reasons for the variable uptake of a pilot for a patient held passport by two groups of pre-assessment nurses.

Finally, Chapter 7 summaries the lessons learned during this study and suggests areas for further research. My personal journey and the impact of undertaking the PhD are also discussed.

Dedication

To my mother, Ruby Quartey-Papafio, who sowed the seed for an interest in diabetes research in me, by example at a tender age and created the opportunities and a motivation in me to become a doctor, twice.

Acknowledgements

I underestimated the extent and degree to which undertaking a PhD would challenge me both academically and personally. In the process of researching and writing I have learnt about myself and grown in unexpected ways. There are many people to thank for supporting me through the process, accompanying me on the journey and weathering the storms as well as sharing the joys.

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List of abbreviations

AACE	American Association of Clinical Endocrinologists
ADA	American Diabetes Association
AR-1	First order correlation
BMI	Body mass index
CABG	Coronary Artery Bypass Graft
CI	Confidence Interval
CVA	Cerebral vascular accident
DCSQ	Diabetes Clinic Satisfaction Questionnaire
DICE	Diabetes Inpatient Care and Education
DISN	Diabetes Inpatient Specialist Nurse
DKA	Diabetic ketoacidosis
DPAR	Diabetes Patient At Risk
DTSQ-IP	Diabetes Treatment Satisfaction Questionnaire for Inpatients
HbA1c	Glycosylated Haemoglobin A1c
HES	Hospital Episode System
HHS	Hyperglycaemic hyperosmolar state
HRG	Health resource group
ICD	International Classification of Disease
IDF	International Diabetes Federation
IMD	Index of Multiple Deprivation
IT	Information Technology
ITU	Intensive therapy unit
IQR	Interquartile range
JBDS	Joint British Diabetes Societies
MeSH	Medical subject headings
NaDIA	National Diabetes Inpatient Audit
NCEPOD	National Confidential Enquiry into Patient Outcome and Death
NICE	Nice Institute of Clinical Excellence

OHA	Oral hypoglycaemic agent
OR	Odds ratio
PAS	Patient Administration System
Rbc	Red blood cell
RCT	Randomised controlled trial
SD	Standard deviation
MI	Myocardial infarction
NIHR	National Institute for Health Research
PVD	Peripheral Vascular Disease

THESIS FORMAT

This thesis is formatted in accordance with the University of Birmingham alternative format thesis guidelines; Regulation 7.4.1 (g) (https://intranet.birmingham.ac.uk/as/studentservices/graduateschool/documents/public/r sa/alternative-format-thesis-guidelines.pdf)

Published manuscripts or those under submission (Chapters 1-6) have been inserted directly into the thesis.

In order to limit duplication between the published research and manuscripts under submission, peer review and revision, and the remainder of the thesis, the Introduction and Conclusion chapters will aim to briefly summarise, then focus on expanding on Chapters 2-6. The Introduction will provide an overview and context for the publication chapters, while the Conclusion will discuss the themes that run throughout the thesis in the current clinical context. For numerical clarity each of these manuscripts are presented as self-contained within the chapters with respect to figures, tables and references. As per thesis guidelines, the page numbering within the publications will not be included in the pagination sequence of the submitted thesis.

List of achievements throughout PhD Studies

Publications and manuscripts related to the thesis

Chapter 2

Akiboye F, Adderley NJ, Martin J, Gokhale K, Rudge GM, Marshall TP, Rajendran R, Nirantharakumar K, Rayman G; DICE team. Impact of the Diabetes Inpatient Care and Education (DICE) project on length of stay and mortality. Diabet Med. 2020 Feb;37(2):277-285. doi: 10.1111/dme.14062. Epub 2019 Aug 2. PMID: 31265148.

Chapter 3

Akiboye F, Sihre HK, Al Mulhem M, Rayman G, Nirantharakumar K, Adderley NJ. Impact of diabetes specialist nurses on inpatient care: A systematic review. Diabetic Medicine. 2021 Mar 30:e14573. doi: 10.1111/dme.14573. Epub ahead of print. PMID: 33783872.

Chapter 4

Akiboye F, Wensley F, Kerr M, Adderley N, Rayman G. The impact of the Diabetes Inpatient Care and Education (DICE) project on harms and complications

Under preparation

An economic evaluation on the impact of the outcomes seen in this chapter is being prepared for publication. This has involved additional data linkage which will show some of the effect sizes smaller than reported in this thesis, however all the outcomes under preparation retain their statistical significance.

Chapter 5

Akiboye F, Rayman G. Management of Hyperglycemia and Diabetes in Orthopedic Surgery. Current Diabetes Reports. 2017 Feb;17(2):13. doi: 10.1007/s11892-017-0839-6. PMID: 28265893; PMCID: PMC5339317.

Chapter 6

Akiboye F, Page E, Nirantharakumar K, Rayman G*, Lindenmeyer A. Evaluating Implementation of the Diabetes Perioperative Passport: A Qualitative focus group Study

Under submission

Page E, Akiboye F, Jackson S, Kerry C, Round R, Rayman G; DICE team*. Perioperative passport: empowering people with diabetes along their surgical journey. Diabetic Medicine. 2017 Dec;34(12):1737-1741. doi: 10.1111/dme.13513. Epub 2017 Oct 20. PMID: 28921676.

Presentations I have given or contributed towards related to the thesis

North European Young Diabetologists Meeting: The impact of the DICE project on length of stay and mortality: Oral, Warwickshire 17-19th May 2017

Royal Society of Medicine, National diabetes inpatient conference: The evidence for diabetes inpatient specialist nurses: oral, 21st September 2017

Diabetes UK Professional Conference: What can we do to improve diabetes inpatient care: The evidence for inpatient diabetes teams: Oral, London 14th March 2018

Diabetes UK professional conference, Arnold Bloom Lecture: Back to the future: The changing landscape of diabetes care, Professor Gerry Rayman 22nd April 2021

CHAPTER 1

Introduction

Diabetes definition

Diabetes mellitus, commonly referred to as diabetes, is a chronic condition of excess glucose in the blood, termed hyperglycaemia. This arises due to problems with the production or action of insulin, a hormone that controls blood glucose levels. Insulin acts as a key to allow glucose from ingested food to be taken into cells, thereby reducing glucose levels in the blood. This process may be impaired due to lack of insulin, which is typically seen in type 1 diabetes, or due to resistance to the actions of insulin in tissues giving rise to type 2 diabetes.

The World Health Organisation published diagnostic criteria for diabetes based on blood glucose measurements in 2006, stated as a fasting plasma glucose of 7.0mmol/L or random venous plasma glucose of 11.1 mmol/L in a patient with symptoms (1). In a patient without symptoms, a second, confirmatory test is required. In 2011 this definition was extended to allow diagnosis using HbA1c with a value of 48 mmol/mol (6.5%) on a laboratory venous sample indicating diabetes. HbA1c is a measurement of how much glucose has bound to red blood cells (2). This measurement reflects the average glucose in the blood stream over a three-month period, as the average lifespan of the red blood cell (rbc) is 120 days.

The size of the problem/ epidemiology

Diabetes is common, affecting 463 million of the global population in 2019 (3). It has become a public health burden of epidemic proportions with an increasing prevalence year on year. The International Diabetes Federation estimates that this figure will rise by 51 % to 700 million people being affected worldwide by 2025(3). Diabetes prevalence across Europe varies with Turkey (11.1%), Germany (10.4%) and Portugal (9.8%) seeing the highest age-

adjusted comparative prevalence and rising (1). The United Kingdom is no exception, with the prevalence of diabetes steadily rising from 3.8 million in 2015 to 4.7 million in 2019 (3; 4).

Type 2 diabetes is the most common type of diabetes accounting for 90% of people with diabetes and affecting one in ten people over 40 years old in the UK. Around 8% of those with diabetes have type 1 diabetes with other acquired and genetic forms making up a fraction of cases (5). A form of diabetes known as gestational diabetes may develop during pregnancy. Women who are diagnosed with this are at increased risk of type 2 diabetes (6).

In the United Kingdom, diabetes accounts for 10% of healthcare spending with the majority of this expenditure spent on the treatment of complications. A similar pattern is seen across Europe, with this region ranked as the third highest for diabetes expenditure by the IDF with an estimated 161.4 billion US dollars spent in 2019[3]. European countries spend between 4.2% (in Ireland) and 23.8 % (in Turkey) of their healthcare expenditure on the management of diabetes and the treatment of its complications (2).

Effects of diabetes

While all cells require glucose as fuel, hyperglycaemia can have a number of detrimental effects in both the short and long term. Over time, the raised glucose levels can cause damage to blood vessels, narrowing them by a process known as atherosclerosis and leading to complications (3). The complications of diabetes are divided into microvascular and macrovascular according to the size of the affected blood vessels. Microvascular complications typically affect the small vessels, with damage seen in the vessels supplying the retina of the eyes, the kidneys, and those supplying nerves, giving rise to retinopathy,

nephropathy and neuropathy respectively. Macrovascular damage in the larger vessels supplying the brain, heart and legs can result in cerebral vascular accident (CVA) or stroke, myocardial infarction (MI) or heart attack, or peripheral vascular disease (PVD) (3). The poor peripheral blood supply of PVD can cause muscular pain due to a lack of blood and oxygen to the tissues when walking or at rest. In severe, sudden blockage of a vessel, critical limb ischaemia may result, which is a vascular emergency requiring urgent surgical intervention. Furthermore, the combination of a poor blood supply to legs in addition to the reduced sensation from peripheral neuropathy can also lead to diabetic foot ulcers and deeper infection of the bone termed osteomyelitis, which may require amputation if untreated (4).

The short-term effects of hyperglycaemia give rise to the symptoms that often precipitate presentation and the subsequent diagnosis of diabetes, particularly in those that develop type 1 diabetes. In order to reduce the rising glucose levels, in the absence or extreme deficiency of insulin, the kidneys excrete some of the excess glucose into the urine resulting in increased urination or polyuria (seen in 92% at presentation). The resultant dehydration that can drive thirst and increased drinking, termed polydipsia (seen in 84% at presentation), and the metabolic shift in ability to use glucose leads to weight loss (seen in 84% at presentation) (5). In type 2 diabetes this process may be more insidious as glucose levels tend to rise more slowly over several years and patients may instead present with non-specific symptoms such as lethargy, recurrent infections or complications of diabetes discussed above (7).

Diabetes emergencies: Diabetic ketoacidosis and Hyperglycaemic hyperosmolar state

Hyperglycaemia can cause significant metabolic shifts at higher levels, and this can result in diabetes emergencies. In those with complete insulin deficiency, generally those with type 1 diabetes, the hyperglycaemia is due to a complete lack of insulin. In this state the body starts to break down fat as an alternative fuel and form metabolites called ketones. These ketones are dangerous at high levels as they are acidic and diabetic ketoacidosis (DKA) can develop as the body loses the ability to compensate for these metabolic changes. The treatment is usually higher doses of insulin to switch the body back to glucose metabolism and this is administered in a hospital setting, sometimes in intensive care, to allow close monitoring. In those with a relative deficiency of insulin, DKA is less likely. However, severe hyperglycaemia without adequate access to fluids can cause significant dehydration, leading to highly concentrated levels of glucose and other metabolites in the blood. This results in a condition known as hyperglycaemic hyperosmolar state (HHS) (8) which also requires hospitalisation with close monitoring for treatment. Both DKA and HHS present with the osmotic symptoms of hyperglycaemia, predominantly thirst, and carry a high risk of mortality.

Hyperglycaemia also impairs the action of the white blood cells responsible for fighting infection and thereby increases propensity to infection. When combined with its other effects, such as increasing the glucose content of the urine, which provides a substrate for bacteria in addition to the poor blood supply and delivery of these important white cells to the affected area, such as foot ulcer, people with diabetes are at an increased risk of infection, particularly in association with hyperglycaemia (9).

Management of diabetes

The strategies for diabetes management are threefold. First, to modify the risk factors that lead to the development of micro- and macrovascular complications. This involves optimising glycaemic control, reducing hyperglycaemia whilst minimising low glucose readings (hypoglycaemia), and managing hypertension and lipid levels. Second is monitoring for complications, with a minimum of annual eye screening, foot screening for neuropathy, and urinalysis to look for protein leaking from the kidneys as an early sign of nephropathy. Finally, if complications or emergencies develop, for instance an infected diabetic foot ulcer or DKA, prompt and appropriate assessment and treatment of assessment and treatment is required (10).

In order to facilitate the management of this increasingly prevalent disease there has, for many years, been an emphasis on ensuring that people with diabetes are educated about the necessary monitoring and potential complications of the disease. This is usually delivered as group educational programmes tailored to those with type 1 or type 2 diabetes. A number of regional and national programmes have been verified for delivery of patient care such as DESMOND and X-PERT for type 2 diabetes and DAFNE and BERTIE online for type 1 diabetes (11; 12). The broad educational foundation that these programmes provide allows specific and individual needs and questions to be addressed in annual reviews.

The multidisciplinary team

With such a complex disease with a wide range of potential complications, a number of skills are required for optimal care for people with diabetes. In order to deliver the necessary education, prescribing, monitoring and management of complications a multidisciplinary team approach is required. This often consists of dieticians, podiatrists, diabetes specialist

nurses, physicians and sometimes psychologists. While the physician is typically responsible for the overall care, much of the care delivery and continuity of care is provided by the diabetes specialist nurse, both in the community and in an inpatient setting (13). This role often encompasses structured group and personal education as well as routine monitoring for complications with specialist nurses who are often the first point of contact for patients. Their central role has been increasing since it was introduced in the 1970s (14), with the scope of the role ever expanding to include prescribing and motivational interviewing.

The challenge of diabetes inpatient care

For people with diabetes hospitalisation, whether primarily related to their diabetes or not, presents a number of challenges, with disruption to their usual routines and a loss of autonomy and control over medication on top of the medical or surgical reason for which they were admitted (15). The timing of meals in hospital can vary compared to people's home pattern, but more importantly the main cooked meal tends to be at lunchtime with lighter food such as a sandwich in the evening, in contrast to the patterns of many who have their evening meal as the main meal. The majority of patients in hospital with diabetes are admitted with other primary problems and are therefore under the care of non-diabetologists (16). These non-specialist teams often do not take diabetes care into account when managing the presenting issue. The primary medical or surgical reason for admission often affects glycaemic control, which is an additional factor on top of the structural and educational challenges faced by inpatients with diabetes.

In patients undergoing surgery these challenges are exacerbated by extended periods of fasting and the physiological stress of the operation, as well as the underlying cause in emergency cases. For planned or elective surgery there are a number of stages and people

involved in the pathway to the final operative procedure, however diabetes care is a crucial thread which is inconsistently managed or may be lost altogether during the process (17).

For many of these reasons the care that inpatients with diabetes receive is suboptimal. This is reflected in longer length of stay, poorer outcomes in both medical and surgical disciplines and higher mortality (18). Having been educated to manage and live day to day with their condition, patients themselves also report lack of confidence in non-specialists managing their diabetes whilst inpatients.

Diabetes Management guidelines

With diabetes predominantly managed in the outpatient setting guidelines there have been established at national level for the frequency of routine assessment, targets for glycaemic, blood pressure and lipid control, and medication management. This guidance is issued by national bodies such as the National Institute for Health and Care Excellence (NICE), with further clarification from joint groups, particularly the Joint British Diabetes Societies (JBDS) on how to deliver this guidance in clinical practice (19; 20).

Diabetes inpatient guidelines aim to maintain glucose levels within a safe range, avoiding either hyper- or hypoglycaemia, preventing the development of complications or emergencies in hospital, and facilitating safe discharge back to community services. Despite these universal aims the approach and resultant guidance varies.

Inpatient guidance

The approach in the United States, recommended by guidance from the American Diabetes Association focuses on optimising glycaemic control, shortening length of stay, and discharge that prevents acute complications and readmission (21). With these aims the hospital standards are prescriptive in their recommendations, suggesting HbA1c testing on

admission, automating glucose control with computer-based insulin protocols for dose adjustment, diabetes specialist input, and tight glycaemic parameters with insulin to be prescribed for persistent hyperglycaemia.

In the United Kingdom, the JBDS for inpatient care examined care throughout the country, taking into account local variation, based on practices that worked well with a focus on patient safety and patient empowerment for supported self-management of glucose. The main principles drawn out of this nationwide project suggest that best care includes multidisciplinary teams, diabetes inpatient teams leading clinical decisions, a body of health care professionals with knowledge and understanding of diabetes, support for patients to manage their diabetes in hospital, and systems to enable hospitals to learn from their mistakes and continue to improve care (20).

Surgical guidance

The JBDS surgical guideline aims to provide a route to seamless care for the patient, from primary care referral, through elective assessment and hospitalisation for surgery, and on to discharge. It focuses on optimising glycaemic control through organisation of these services and close monitoring of the patient (20).

The guidance for inpatient care is more recent, with plans for ongoing revision and refinement of these as research emerges in this field. Despite these guidelines, staffing, practice and outcomes vary nationally as shown by national audit.

Monitoring the quality of diabetes inpatient care

In order to measure, benchmark and share the quality of diabetes inpatient care, the National Diabetes Inpatient Audit (NaDIA) was set up in 2011 (22). It invited hospitals across England and Wales to collect and submit data across a range of inpatient diabetes care

measures. This one-day snapshot gained the participation of 206 hospitals or sites in its first year. Data collected looks back over the preceding ten days and includes length of stay, drug errors, monitoring for complications such as heel ulcers, development of inpatient complications such as DKA, HHS and foot ulcers, as well as measurements of glucose control across the 10-day period. It aims to ascertain for each trust whether harm resulted from inpatient stay, whether diabetes management minimised the risks of avoidable complications, and also what the patient experience was through a patient questionnaire where possible.

In the years since its inception, NaDIA has continued to measure these aspects of patient care on an almost annual basis for participating sites across England and Wales allowing them to compare their performance nationally. In addition to benchmarking, repeated audit enables hospitals to measure changes in their service delivery and care for inpatients with diabetes over time. The audit has documented the substantial service need and allowed 90% of participating sites to receive transformational funding to use towards improvements in staffing levels of diabetes consultants, specialist nurses, dieticians and podiatry services. There has also been a slow, but steady increase in the adoption of electronic prescribing, which is associated with reduced insulin errors. The use of electronic prescribing grew in participating sites across England and Wales from 16.1% in 2013 to 34.6% in 2018 (23; 24).

One area that has remained a challenge to improve has been the medical care received by surgical patients. The National Confidential Enquiry into Patient Outcome and Death (NCEPOD) review of 2018 looked back at 509 case notes of people with type 1 and type 2 diabetes who had undergone surgery (25). The review highlighted the deficiency in continuity of care throughout the perioperative pathway, with key assessments such as

nutritional assessments and medicine reconciliation not being carried out in a significant proportion of cases. There was also a failure to prioritise patients with diabetes on operating lists in 19.4% of cases, leading to prolonged fasting. Overall, the examination found room for improvement in clinical care in 35.8% of cases examined.

The need for service development in diabetes

With rising demand and suboptimal care for people with diabetes, the need to improve standards is both urgent and important. The challenge is multifaceted and therefore the most effective solution is likely to be one that addresses many of the barriers to optimal care in the hospital setting. Furthermore, any systems developed must be deliverable in a sustainable and cost-effective fashion.

This thesis examines the impact of the first known highly multifaceted programme, the Diabetes Inpatient Care and Education (DICE) project.

Background to DICE

Prior to introduction of the DICE there was one full time Nurse working 1 whole time equivalent (WTE) involved in delivering a diabetes service with the support of a diabetes consultant. The nurse's activity involved visiting the wards to enquire about any newly admitted or transferred patients with diabetes or any concerns the nursing staff had around diabetes care.

In order to improve care for inpatients with diabetes, two additional nurses from other clinical teams, one medicine and surgery, were seconded for training as DISNs over the course of 6 months. During this time, they collected bedside data and observed how the diabetes team delivered care in the hospital. With the benefits of some clinical distance in observing these care interactions, their previous ward experience, and the perspective they

brought to the team, the training DISNs contributed to regular discussion about potential innovations within service. These contributions as well as consideration of the most frequently asked questions and challenges encountered and enabled the diabetes inpatient team to address these issues. Together with a research fellow, Rajesh, Rajendran, the diabetes team were able to implement a number of researched, evidenced, bespoke and novel strategies to proactively and more robustly enable ward staff to manage patients with diabetes and refer appropriately. These are outlined below.

The Diabetes Inpatient Care and Education (DICE) project: an overview

The Diabetes Inpatient Care and Education (DICE) project is a whole systems approach to addressing the many challenges of diabetes care in a district general hospital in the United Kingdom. It takes a proactive approach to diabetes inpatient care, aiming to improve the standard of care and rapidly identify and respond to a changing healthcare climate and the growing demand of patients who receive this care.

There was a six-month period of monitoring and observation between January and June 2013. This was followed by six months of discussion, planning and preparation for the implementation of strategies to address the observed challenges within the hospital for patients with diabetes. These novel initiatives were then implemented as the DICE project between January and June 2014 with a second six-month period of monitoring, assessment and feedback after. The project is ongoing and ever evolving as new challenges come to light and novel ways to address them are found.

The whole systems approach implemented between January and June 2014 and its impact is explored within this thesis and is detailed below.

The DICE programme

The initial DICE programme comprised six key elements aimed at addressing the many challenges of diabetes inpatient care:

- diabetes care pathway
    - unified glucose and insulin chart
    - foot check
    - Diabetes Patient At Risk (DPAR) scoring system
    - Insulin self-management check list
    - Safe discharge checklist
- electronic tools
    - daily identification of inpatients with diabetes
    - hypoglycaemia alert system
- Induction programme for new staff
- Regular audit
- DICE team meetings
- Staffing with dedicated Diabetes inpatient nurses

The DICE care pathway

The DICE care pathway is an eight-page booklet designed to address the needs of patients from admission to discharge. It is a comprehensive document comprising the necessary monitoring and documentation required for many aspects of good diabetes inpatient care as well as being a resource for ward staff, providing guidance, prompts, treatment algorithms and specialist referral criteria. All patients with diabetes admitted to hospital require a DICE care pathway, and this is often initiated by the admitting nurse, but can be started by any health care professional.

On the first page the importance of identifying the type of diabetes is highlighted with a prompt to ensure that staff are aware of the patient's status from admission and of care implications related to their diabetes type (e.g. never stop insulin in type 1 patients). Staff are then prompted to assess the patient's need for specialist input via a novel scoring

system [the Diabetes Patient At Risk score (DPAR)]. This risk score stratifies patients for review by either the diabetes inpatient team and/or the diabetes foot team. The urgency of review, and the most appropriate specialist for the review is embedded in the referral, so that a consultant diabetologist alone or together with a diabetes specialist podiatrist or Diabetes Inpatient Specialist Nurse (DISN) attends appropriately for diabetic emergencies, diabetic foot syndrome or to provide patient or staff advice respectively.

In this unique system a high score prompts an online referral which can be made quickly and without the need for the approval of the admitting doctor, a factor which was previously noted to delay referral or prevent essential referral for specialist input entirely. Being online also allows accurate data collection for audit purposes as detailed further below.

Foot care with regular foot and particularly heel inspections is a vital component of good diabetes inpatient care. In order to prompt this important practice and ensure that staff are able to assess patients the pathway contains an admission foot check form which includes instructions on how to perform a simple foot examination. Ongoing daily foot examinations are prompted by a space within the booklet for daily heel checks. This is coupled with guidance for staff on when and how to refer to the multidisciplinary foot team, again with an online referral and a reminder to bleep as urgency necessitates.

Insulin use carries a significant risk, with insulin errors among the highest injectable drug “never events” leading to death in hospitalised patients. Never events are serious incidents that are deemed completely avoidable, as strong guidance or systems would prevent their occurrence. The list of never events are set by NHS improvement with national guidance and safety recommendations that form a robust safety framework, acting as a barrier, which should prevent these Serious Incidents from occurring in any NHS health care setting (26).

The pathway booklet aims to address the issus around insulin errors in a number of ways. For patients able to administer and self-manage their insulin, it is usually safe for them to continue to do so in hospital. A self-management checklist is included in the booklet which staff can complete to facilitate self-administration of insulin, which can be reviewed if the clinical situation changes.

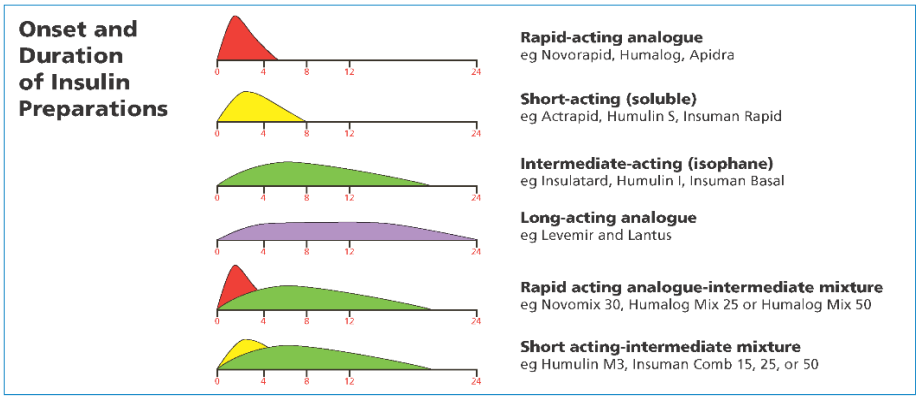
The DICE pathway combines insulin prescription and adjustments with glucose monitoring in a user-friendly chart. A visual prompt for the target glucose range is included within the pathway, and a treatment algorithm is included to ensure that ward staff initiate treatment for hyperglycaemia. The booklet also contains specific treatment charts for the diabetic emergencies DKA and HHS, and charts for monitoring and adjustment of intravenous insulin infusions for those patients who are not eating.

Insulin prescription errors are common in the absence of electronic prescribing; NaDIA showed these errors reduced from 6.3 to 1.9% between 2010 and 2013 (24). However, in the NCEPOD review of perioperative diabetes care the rate of prescription errors was high at 48.6%. Errors in prescription of insulin doses was reported at 16.1% nationally (25).

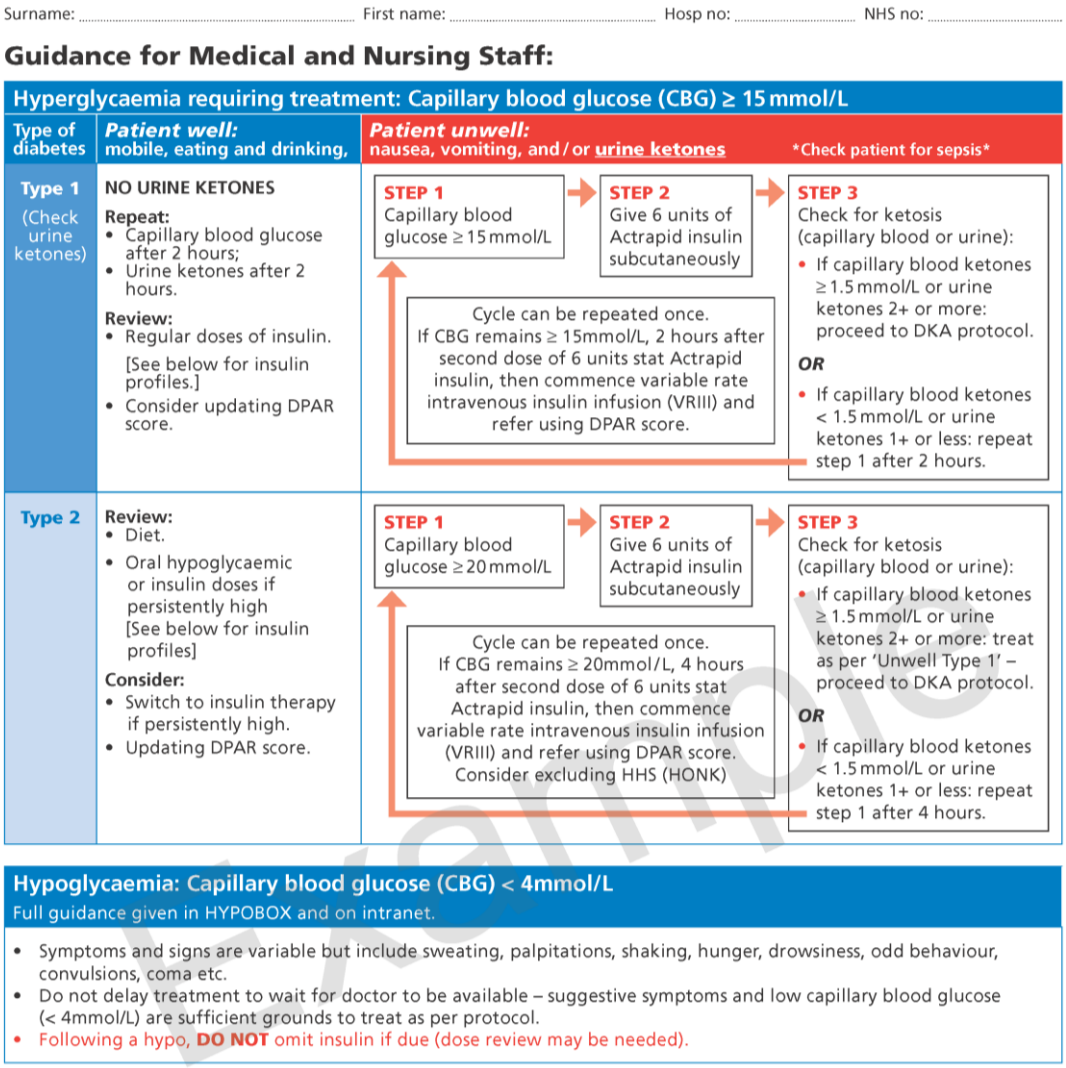
In order to minimise the risk of incorrect or inappropriate insulin being administered, an illustration of the different types of insulin, with examples and their duration of action, is included in the DICE pathway.

Finally, the pathway contains a discharge checklist of things to consider in order to facilitate safe transition for patients out of the hospital and back to their primary care physician or hospital diabetes care provider.

An illustration of the insulin time action profiles for the different types of insulins and an algorithm to direct management of hyperglycaemia are shown below in supplementary figures 1 and 2.

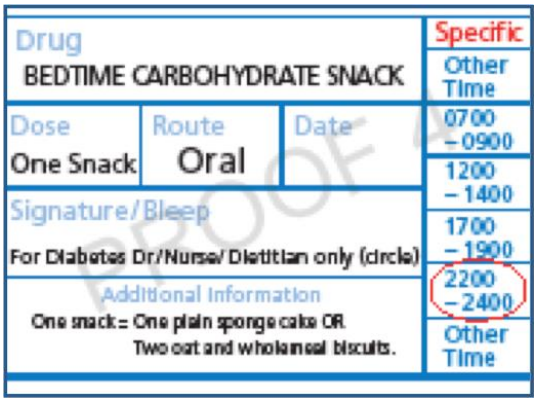


Supplementary figure 1. DICE chart illustration of insulin profiles.



Supplementary figure 2. DICE chart illustration of hyperglycaemia treatment algorithm.

For those on insulin or sulphonylureas, there is also the requirement to prescribe a bedtime snack to prevent overnight hypoglycaemia, which we previously reported to be an issue in hospitalised patients (3) (supplementary figure 3).



Supplementary figure 3. DICE chart illustration of bedtime snack sticker.

Proactive patient identification and management of hypoglycaemia

Proactive management of hospitalised patients with diabetes is a key component of the DICE programme. There were two electronic initiatives developed in conjunction with the hospital information technology (IT) department that enabled a change to proactive working upon implementing the programme. These are outlined below.

Identification and review of all new diabetes admissions

In order to accurately identify newly admitted patients for diabetes inpatient team review, patients with a diagnosis of diabetes were triangulated from previous admission records, attendance at the Diabetes Centre and the outpatient diabetes care pathway electronic medical records system (SystmOne). From these three sources an automated daily list was generated prior to the start of the working day allowing prompt review of patients who had not been referred via the DPAR system for medication review and adjustment, initiation of patient self-management where appropriate, and other measures to prevent hypo- and hyperglycaemia.

At review, the missed or incorrect prescriptions could then be highlighted, and for those patients on the sulphonylurea group of oral hypoglycaemic agents a bedtime snack

prescribed in the drug chart to prevent hypoglycaemia, which is more common overnight. The snack prescription sticker is illustrated in supplementary figure 3.

Bespoke hypoglycaemia alert using web-linked point-of-care blood glucose meters

The point of care glucose meters used to measure inpatient glucose values across the hospital were linked to a web-based system (FreeStyle Precision Pro Blood Glucose Monitoring System™ - Abbott Diabetes Care, Witney, UK). The hospital information technology department then set up a bespoke system using parameters set by the diabetes team to generate a list of all patients with any episodes of hypoglycaemia measured within the trust in the previous 24 hours. This hypoglycaemia alert system provides crucial information, enabling the DISNs to prioritise these at-risk patients during ward visits and make prompt adjustments to medication, aiming to preventing further harm due to recurrent hypoglycaemia. This unique system has been shown to reduce recurrent hypoglycaemia by 35% (27).

Induction programme for new staff

In order to address knowledge gaps within training and the routine rotation of junior doctors, diabetes training was included in their induction. This involved introduction to the DICE pathway and explanation of how to use it, with common pitfalls highlighted. Scenario-based teaching was a key element of this induction programme and it was shown to be effective in significantly increasing the confidence of doctors in managing inpatients with diabetes.

Regular audit

It is known that simply taking steps to measure an outcome can improve the measured value (28). An audit was set up based on a summary of the National Diabetes Inpatient Audit

and conducted as a snapshot on a single day each month. This allowed the diabetes team to gain information on the impact of developments and changes within the DICE programme and champion wards and areas which were doing well or support struggling ward staff or areas with targeted education. The outcome of the audits and ways of improving care further were discussed within the team.

DICE team meetings

The innovations within the DICE programme and their impact and progress along with any challenges identified within the trust that might hinder the delivery of optimal diabetes inpatient care were discussed in a weekly team meeting. These meetings were attended by all involved in the delivery of inpatient diabetes care, including consultant, research registrar, DISNs, podiatrists and practice manager. All were given the opportunity to raise issues and solutions could be discussed as a team allowing different perspectives and ideas to be shared.

Ideas that might be implemented locally from published work were also discussed and developed into projects, smaller audits or studies.

Staffing with dedicated Diabetes inpatient nurses

In order to provide this service, two additional nurses were recruited to the team from other settings. During the first six months they collected data about current practice as a baseline measurement of care being provided for inpatients, and learnt about inpatient diabetes care. They were also able to observe the care being provided and offer a perspective with “fresh eyes” on how care might be improved for inpatients with diabetes.

These nurses provided the bulk of the inpatient care delivery, with consultant support, to increase the weekday diabetes care to a seven-day service.

Measuring the impact of DICE using hospital administrative data

In order to determine the impact of DICE on the patient group with diabetes attending the hospital in comparison to those without diabetes, a routinely collected dataset was used. Patient Administration System (PAS) data is collected for every patient attending the hospital in any capacity across all departments. It comprises patient demographics, comorbidities, diagnoses, intensive care admissions and procedures carried out, which are compiled from discharge summaries, which include admission and discharge dates. This data is collected in all hospitals in the UK and feeds into the Hospital Episode System (HES) database which allows hospitals to be paid for the care delivered each quarter. As this data is routinely collected for all patients it allows comparison of patients with diabetes and those without.

In this thesis PAS data is used to explore the impact of the DICE project using the additional quasi-experimental technique of interrupted time series analysis to assess the changes in relation to seasonal or background trends.

The impact of diabetes inpatient nurses a systematic review

Diabetes specialist nurses are not ubiquitous across the NHS with NaDIA 2017 reporting that one in five hospitals does not have a dedicated DISN or specialist nursing team. The reasons for this discrepancy are unclear and likely to be multifactorial.

In order to fund new posts for diabetes specialist nurses, the case for their cost saving benefit in addition to the clinical need often has to be made. The cost-effectiveness of DISNs has been shown, with a specialist nursing team investment of £5 million across 54 trust estimated to yield savings of £14 million, a net saving of £9 million per year (29). This cost is predominantly measured in bed day savings. While a number of position statements advocate for inpatient diabetes nursing teams in every hospital the National Diabetes Inpatient Audit has not shown these recommendations translating into consistent action.

This thesis explores the many ways the employment of diabetes specialist nurses may impact patient care, through a systematic review of the literature, with the aim of giving a balanced and realistic appraisal of their impact and utility in the current pressured climate. It also displays the breadth of research that studies in this field have covered, identifying areas for further investigation.

The impact of DICE on inpatient complications

As the role of specialist nurses evolved in a range of specialities, from multiple sclerosis to tissue viability, the question of how to best measure their impact was raised. In 2003, Doran suggested that softer outcomes that related directly to the role of the nurse, termed 'nurse related outcomes', be measured. These outcomes are more difficult to measure, however, potentially provide richer information regarding the impact of specialist nurses beyond the cost saving implications. Investigation of this area may also bridge knowledge gaps in the potential ways by which employment of DISNs reduces length of stay.

Hyperglycaemia is known to be associated with an increased propensity to infection and one of the ways diabetes specialist nurses are thought to reduce patient length of stay is by optimising glycaemic control (30). It has been presumed that the reduction in length of stay

may be related to fewer complications during the inpatient stay. This, however, is quite difficult to measure in many hospitals.

PAS data, which uses coded data from discharge summaries, does not distinguish between pre-existing comorbidities and new diagnoses during the current admission. Obtaining this information in a digital form for analysis is a considerable challenge in many hospitals. While there is currently a movement towards digitalising notes, this has largely been through the scanning of written notes rather than entry of written/typed text in most trusts. Unfortunately, the challenge remains that the only way to gather this information on inpatient harm due to infective or other macro- or microvascular complications of diabetes is by manual review of patient notes in many trusts.

While coders are trained specifically to extract information from the discharge summaries, the information that is communicated within these is often summarised for the reference of the general practitioner and patient. The accuracy of this information in providing a comprehensive representation of the events during the patient's admission is variable and has been reported as low as 86% in accuracy (22).

In order to gain a more accurate representation of the impact of DICE on complications, a manual notes audit for pre-agreed diagnoses was carried out on all patients admitted overnight with diabetes for a six-month period before and after the intervention. Staff received training for this, and the information was captured electronically.

In this thesis this bedside data is analysed before and after the implementation of the DICE programme, to enable a crucial and rare assessment of the complications associated with hospitalisation for patients with diabetes and the programme's impact on these.

The impact of diabetes and hyperglycaemia on orthopaedic outcomes: a guidance pathway

The strongest evidence for the impact of hyperglycaemia and diabetes on patient outcomes is within surgery. Hyperglycaemia in the absence of diabetes has been found to impair wound healing and is a risk factor for increased ITU and all-cause mortality post-operatively (31). Perhaps the largest infective risk in those with poor glycaemic control perioperatively is where metal work is used, as is often the case in orthopaedic surgery (23). Here a deeper infection has potentially weightier consequences as it is likely to require repeat surgery to remove the infected prosthesis rather than antibiotics.

This thesis reviews the evidence for perioperative complications in orthopaedics with diabetes and hyperglycaemia, as well as evidence for optimal treatment of diabetes in this area. Opportunities to improve glycaemic control along the patient journey to surgery are highlighted, with a guidance pathway suggested to optimise care for patients with diabetes who require surgery.

Improving care in the perioperative pathway

The journey to surgery is a complex pathway involving a series of steps. First, primary care, where a physician or practitioner refers the patient to the hospital surgical pathway. Then once within secondary care, the patient will usually pass through surgical outpatients and preoperative assessment before hospital admission for surgery. Next post-operative care before to finally being discharged back to the community or primary care provider. There are often different professionals or teams leading key tasks to facilitate safe, efficient assessment for surgery, the operation and recovery prior to discharge.

While each of these professionals plays an important role, diabetes management is often not given the attention required given the impact it has on patient outcomes. In the outpatient setting the management of diabetes has increasingly focused on providing education and tools for those with diabetes to manage the condition themselves, and to be aware of the consequences of poor glycaemic control (32). Maternity records also empower women to hold information necessary for their perinatal care and they are encouraged to take this to each appointment or professional contact to provide some clinical continuity (33).

In this study, a diabetes passport was produced to address the challenges of continuity of care during the complex multistep perioperative pathway for people with diabetes. The booklet was developed with the aim of informing and empowering patients with diabetes from surgical assessment in secondary care to discharge. It moves chronologically through the pathway and comprises a number of sections. The passport contains information pages for patients about what to expect at each stage in reference to their diabetes care, there are pages for the health care professionals to complete, at pre-assessment, engaging them in this interaction with a predetermined structure, and finally there are pages for the patient to complete prompting their ownership of their diabetes care as they move through the pathway.

The challenges of implementing a diabetes perioperative passport in the hospital setting

Despite evidence for the efficacy of novel technologies, guidelines and tools piloted in controlled clinical areas or on a small scale, the adoption and embedding of new practices

into routine clinical practice remains challenging. Studies show that failure of implementation or end user dissatisfaction affects up to 70% of new innovations in practice.

The barriers and facilitators to implementation of various clinician- and nurse-delivered technologies have been studied in a range of areas and the hospital setting carries particular challenges (34).

The final piece of research for this thesis explores the challenges of implementing the patient-empowering perioperative passport in the inpatient setting by comparing the perception of the passport in two pre-operative nursing groups with contrasting responses to a pilot where they were invited to administer it.

This thesis aims to examine the impact of diabetes inpatient specialist nurses through systematic review,

and uses real world data in a district general hospital to explore their impact in the delivery of a multisystem approach to diabetes inpatient care. The potential for improvements in care in the perioperative process are highlighted, with a review of the evidence and a suggested guideline for pathway improvements in orthopaedic surgery. Finally, the challenges of engaging non-diabetes specialist staff in the implementation of diabetes care strategies in the hospital setting are explored.

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CHAPTER 2

Chapter 2: Impact of the Diabetes Inpatient Care and Education (DICE) project on length of stay and mortality

This chapter uses routinely collected patient administration system (PAS) data to measure outcomes from it. As the primary researcher I became familiar with the information coded within this data source. From this I was able to identify the most robust metrics for data extraction for outcomes and potential confounders. In designing the study using the PAS data I took into account the limitations of the dataset.

The data extraction was carried out with the assistance of the hospital information technology team who pseudonymised patient information in line with information governance.

There were further considerations I took to complete the analysis, which involved finding the best ways to interrogate the data to measure and correct outcomes. For example, the importance of re-admissions as a secondary outcome and the timeframe after which to measure the readmission, 30 days or 90 days. For this, the previous literature was examined, and a consensus made on discussion with supervisors.

I coded and then carried out the analysis with some assistance from a collaborating statistician for additional modelling in the interrupted time series analysis.

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Research: Educational and Psychological Aspects

Impact of the Diabetes Inpatient Care and Education (DICE) project on length of stay and mortality

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Abstract

Aim To determine whether the Diabetes Inpatient Care and Education (DICE) programme, a whole-systems approach to managing inpatient diabetes, reduces length of stay, in-hospital mortality and readmissions.

Research design and methods Diabetes Inpatient Care and Education initiatives included identification of all diabetes admissions, a novel DICE care-pathway, an online system for prioritizing referrals, use of web-linked glucose meters, an enhanced diabetes team, and novel diabetes training for doctors. Patient administration system data were extracted for people admitted to Ipswich Hospital from January 2008 to June 2016. Logistic regression was used to compare binary outcomes (mortality, 30-day readmissions) 6 months before and after the intervention; generalized estimating equations were used to compare lengths of stay. Interrupted time series analysis was performed over the full 7.5-year period to account for secular trends.

Results Before-and-after analysis revealed a significant reduction in lengths of stay for people with and without diabetes: relative ratios 0.89 (95% CI 0.83, 0.97) and 0.93 (95% CI 0.90, 0.96), respectively; however, in interrupted time series analysis the change in long-term trend for length of stay following the intervention was significant only for people with diabetes (P 0.017 vs P 0.48). Odds ratios for mortality were 0.63 (0.48, 0.82) and 0.81 (0.70, 0.93) in people with and without diabetes, respectively; however, the change in trend was not significant in people with diabetes, while there was an apparent increase in those without diabetes. There was no significant change in 30-day readmissions, but interrupted time series analysis showed a rising trend in both groups.

Conclusion The DICE programme was associated with a shorter length of stay in inpatients with diabetes beyond that observed in people without diabetes.

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Introduction

Inpatient diabetes care is a growing concern. Almost two thirds of diabetes healthcare expenses are spent on hospital ization, with a minority of people with diabetes contributing to the majority of this cost [1]. The ever increasing preva lence of diabetes in the general population has resulted in a steady rise in beds occupied by people with diabetes, from one in eight in 2011 to one in six in the National Diabetes Inpatient Audit, conducted in 2017 [2,3]. At this rate, projecting forward, it has been estimated that by 2030 more than one in four inpatients will have diabetes. Indeed, in some UK hospitals the prevalence is as high as 30% [3], a prevalence already exceeded in some US states [4].

In 2011, the National Health Service in England was estimated to spend between £2.3 bn and £2.5 bn per year on inpatient care for people with diabetes, which is ~11% of total inpatient care expenditure and ~25% of the total expenditure on diabetes care [5]. More sizable estimates have been made for the American (25%), French (38%) and Italian (57%) healthcare systems, confirming that inpatient care is the largest component of medical expenditure for diabetes [1,6].

People with diabetes are more frequently admitted to hospital than those without the condition, with diabetes reported to be among the five most prevalent comorbidities in hospitalized and readmitted patients [7]. Despite its documented frequency, most people with diabetes are hospitalized for another reason, with diabetes related

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What's new?

- People hospitalized with diabetes have poorer outcomes and longer length of stay than those without diabetes.
- We report the impact of a multifaceted, whole systems approach to diabetes care.
- Interrupted time series analysis was used to supplement the commonly used before and after analysis, highlighting the strength of this quasi experimental methodology.
- Our data show that a nurse delivered care programme can produce sustained and ongoing reductions in length of stay for people with diabetes in the National Health Service today.

emergencies primarily implicated in fewer than 10% of admissions [3]. The majority of inpatients with diabetes are therefore under the care of non diabetologists within both medical and surgical specialities [2].

The care that people with diabetes receive is suboptimal. Inpatients with diabetes have poorer clinical outcomes with longer length of stay [8], higher complication rates [9], and increased mortality [10] compared to people without diabetes. The reasons for these differences are not fully understood, however, glycaemic control has been implicated, with hyperglycaemia thought to account for higher infection rates [11] and hypoglycaemia associated with greater mortality [12].

Several measures have been used as indicators of the quality of hospital care, including length of stay, readmission rates and mortality [13,14]. In the multi morbid individual with diabetes in whom managing glycaemic control during illness within the hospital environment is challenging, a reduction in length of stay is thought to indicate improved quality of care, although not if at the expense of readmissions.

In the current financial climate, cost effective ways to improve care and outcomes in this growing cohort are of paramount importance. A number of strategies have been adopted by some hospitals; these include protocols for glucose management, staff education programmes and alert systems such as the 'Think Glucose' programme to identify those requiring specialist team review [15]. Their success in reducing length of stay and hospital acquired diabetes complications, such as diabetic ketoacidosis or foot ulceration, is not known. Some studies suggest that the availability of diabetes specialist nurses reduces length of stay [16,17], but these studies were undertaken some years ago when length of stay for all inpatients was much longer than today. Nevertheless, based on these publications, the economic case for inpatient diabetes teams was made in a document by Marion Kerr in 2011 [5]; this showed the cost of diabetes inpatient nurses was repaid within 3 years. With the increasing emphasis on ambulatory management and early discharge, it is not clear whether similar bed day savings would be seen today.

While randomized controlled trials (RCTs) are the research 'gold standard', they can be impractical, and in some cases unethical, to conduct. Before and after studies analysing observational data are most commonly used to assess the impact of health service interventions. These studies may overestimate effect size as they do not assess the ongoing effect of an intervention, which may diminish or return to baseline soon after the post intervention analysis. Conversely, before and after studies may fail to observe a real effect if the time between the intervention, behavioural change and the subsequent follow up period is insufficient for the impact to become evident.

Recently, the application of quasi experimental analysis to observational data has allowed researchers to design methodologies to circumvent some of these issues. Interrupted time series analysis is one such technique, and has a number of advantages over RCTs and before and after studies.

An interrupted time series design uses data from multiple time periods to estimate an intervention effect whilst adjusting for any underlying secular trend [18]. It allows the comparison of pre and post intervention periods without the requirement for a comparison group [19], and enables examination of changes to the outcome post intervention with an allowance for natural variation in the outcome over time.

We introduced a whole systems approach to improving diabetes inpatient care in Ipswich Hospital using technology, education, protocols and pathways for identifying patients most in need of specialist diabetes input (outlined below). An interrupted time series analysis was used to supplement a before and after analysis to assess the impact of this whole systems approach.

The Diabetes Inpatient Care and Education programme

The Diabetes Inpatient Care and Education (DICE) programme was designed and developed as a whole systems approach to managing inpatient diabetes. It comprised a number of changes to existing diabetes practices.

The DICE care pathway

Every patient with diabetes is initiated on an eight page diabetes pathway, the DICE chart/booklet, which remains with them throughout their stay. It is also an education tool for all healthcare professionals directing care. Within the DICE booklet there are user friendly glucose and insulin charts designed to improve patient safety, a foot check form to be completed on admission, with instructions on how to perform a simple foot examination using the novel Ipswich Touch Test, as well as instructions on who and how to refer to the multidisciplinary foot team [20]. The pathway contains the unique Diabetic Patient At Risk (DPAR) scoring system, which empowers ward staff to refer patients to the

diabetes specialist nurse and foot team, and enables prioritization according to clinical urgency. The system has been very well received by medical and nursing staff and, since implementation, >95% of referrals have been reviewed within our prespecified best practice period [21].

The booklet contains a checklist to facilitate insulin self management and finally a safe discharge checklist. The DICE booklet is described in greater detail in the Supporting Information which includes illustrations of insulin action profiles, the hypoglycaemic treatment algorithm and the bedtime snack sticker (Figures S1, S2, S3).

The programme also comprised a number of other interventions developed by the DICE team. These include an electronic system to identify all people admitted with diabetes and a hypoglycaemia alert system using web linked point of care blood glucose meters (outlined in Appendix S1).

Novel induction programme for junior doctors

We introduced an induction programme for junior doctors based on common case scenarios and adapted this to include training in the use of the DICE pathway. This was positively evaluated by the trainees [22].

Staffing

Key to delivering these changes in practice was the employment of additional diabetes inpatient specialist nurses, who, in addition to the existing specialist nurse, were equivalent to 2.5 full time staff members. This enabled 7 day working, providing a morning only service at the weekend. More than 90% of inpatients with diabetes were seen by a diabetes inpatient specialist nurse.

This multifaceted service was implemented across all the medical, surgical, haematology and oncology wards from 1 July 2013. Randomization was considered unethical as it would remove access to medication adjustments following a hypoglycaemic episode and restrict appropriate specialist review.

Aims of the diabetes inpatient specialist nurses were as follows:

1. To facilitate self care where appropriate, and to educate and support patients in their diabetes care.
2. To educate and support non specialist healthcare professionals in caring for people with diabetes.
3. To avoid hypoglycaemia through proactive adjustment of hypoglycaemic oral medication and insulin on admission, prescription of a bedtime snack, and targeting first events to prevent recurrence.
4. To reduce hospital acquired foot complications by auditing foot examinations and facilitating foot protection for those at risk, and prompt referral of those with foot complications to the multidisciplinary foot team.
5. To optimize glycaemic control, aiming for glucose readings of between 6 and 12 mmol/l where appropriate.
6. To facilitate safe and early discharge and to prevent readmission.

The aim of the present study was to investigate the effect of the DICE programme on mortality, length of stay and 30 day readmissions of inpatients with diabetes at Ipswich Hospital NHS Trust, using routinely collected administrative data for patients admitted to the trust between January 2008 and June 2016.

Methods

Study design

A single centre before and after study was conducted, supplemented by an interrupted time series analysis to reveal any background trends and changes in care after implementation of the DICE programme.

Source of data

Data were extracted from the patient administration system at Ipswich Hospital NHS Trust. For the before and after study, an extract was taken to compare identical 6 month periods, 1 January 2013 to 30 June 2013 and 1 January 2014 to 30 June 2014, i.e. prior to and after the implementation of the DICE programme (1 July 2013 to 31 December 2013). For the interrupted time series analysis, a second extract was taken from 1 January 2008 to 30 June 2016.

Population

Adults with a primary or secondary diagnosis of diabetes defined by International Classification of Disease (ICD) 10 codes E10 to E14 in the patient administration system data were the population of interest. Patients without a diagnostic code of diabetes were used as a negative control group to assess the impact of temporal trends and changes in non diabetes care processes that might impact on the outcomes of people with diabetes.

Only individuals admitted under specialities that were routinely involved in the in the DICE project were included in the analysis; therefore, paediatrics, neonatology and obstetrics were excluded, accounting for 97 beds of this 587 bed hospital. Day case procedures were also excluded.

Covariates for before-and-after analysis

Demographic information (age and sex), ethnicity, index of multiple deprivation category, admission and discharge times (to calculate length of stay), method of discharge, type of admission (emergency or elective), intensive therapy unit stay, healthcare resource group codes, and comorbidities

were obtained from the patient administration system data. A modified Charlson comorbidity score (excluding diabetes) was calculated using ICD 10 codes for comorbidities. The 2015 healthcare resource group categories were applied to the full dataset.

Analysis

A before and after analysis was performed, followed by an interrupted time series analysis.

Before and after analysis

Outcomes in the 6 month periods before and after implementation of the DICE project were compared. Pre DICE analysis was performed in the populations with and without diabetes from 1 January 2013 to 30 June 2013, and post DICE analysis from 1 January 2014 to 30 June 2014. This allowed assessment of whether the intervention led to a change in each of the outcomes in people with diabetes above any difference observed in people without diabetes.

Primary outcomes were length of stay and mortality. Length of stay was derived in hours as the date and time of discharge minus the date and time of admission. The secondary outcome was 30 day emergency readmission rate.

Baseline characteristics are presented as mean (SD) or median (interquartile range) for continuous variables, and as proportions for categorical/binary variables.

Crude (unadjusted) and adjusted odds ratios for mortality, comparing pre and post DICE in patients both with and without diabetes, were calculated using logistic regression.

Length of stay data were found to be skewed; crude and adjusted relative ratios were therefore calculated using generalized estimating equations with log link normal distribution. This modelling accounted for people readmitted multiple times to the hospital within the 6 month periods analysed.

Emergency readmission rates up to 30 days after discharge for both elective and non elective care were analysed to assess for any negative impact from possible premature discharges. Crude and adjusted odds ratios for 30 day readmissions were calculated using logistic regression.

For all outcomes, the following potential confounders were included in the adjusted models: age, sex, ethnic group, index of multiple deprivation quintile, healthcare resource group category, intensive therapy unit episode, modified Charlson comorbidity score, and emergency/elective admission.

Time series analysis

An interrupted time series analysis was performed using segmented regression to adjust for any underlying secular trend.

Data were available for 66 months prior to the intervention and 30 months after the intervention. An aggregate dataset containing monthly averages was created for the analysis. For mortality and 30 day readmission, the number of people who had died or who were readmitted within 30 days was calculated. For length of stay, the monthly mean was calculated using the raw length of stay data.

Mortality and readmission count data were analysed using generalized estimating equation Poisson models, with an offset for the monthly admissions population. For length of stay a generalized estimating equation linear model was fitted to the data. Fixed effects were included for time, intervention initiation, and intervention termination. Two interactions were included: time and intervention initiation; and time and intervention termination (Appendix S2). To allow for auto correlation, we checked autocorrelation and partial autocorrelation plots. A first order autocorrelation (AR 1) was included. The analysis was conducted independently for people with and without diabetes.

All statistical analyses were carried out using STATA 14 and 15. The interrupted time series analysis was carried out using the generalized estimating equation command in STATA, which allows the specification of a first order correlation.

Results

Before and after analysis

In the 6 months before implementation, 2337 patients with diabetes and 13 765 patients without diabetes were admitted to the hospital in the included specialities. In the 6 months after implementation, 2433 people with and 14 290 people without diabetes were admitted. Those with diabetes were older, and a higher proportion were men, had one or more comorbidities and had an emergency admission compared to people without diabetes (Table 1).

In people with diabetes, the mortality rate decreased from 6.4% in the pre intervention period to 4.4% in the post intervention period; in people without diabetes, the mortality rate decreased from 3.7% to 3.1%. The adjusted odds ratio for the change in mortality pre and post intervention was 0.63 (95% CI 0.48, 0.82) in people with diabetes and 0.81 (95% CI 0.70, 0.93) in those without.

The mean length of stay reduced from 7.5 to 6.7 days in those with diabetes and from 5.0 to 4.7 days in patients without. The median reductions in length of stay were 0.4 and 0.1 days, respectively. The adjusted relative ratio for length of stay before and after the intervention was 0.89 (95% CI 0.83, 0.97) and 0.93 (95% CI 0.90, 0.96) in people with and without diabetes, respectively.

Adjusted odds ratios for 30 day readmissions were not statistically significant: 0.96 (95% CI 0.82, 1.12) and 1.04 (95% CI 0.96, 1.12) in people with and without diabetes, respectively (Table 2).

Interrupted time series analysis

The number and demographic characteristics (sex and age) of people included in the interrupted time series analysis are

Table 1 Baseline characteristics of individuals included in the before and after analysis

	2013		2014	
	Non diabetes	Diabetes	Non diabetes	Diabetes
Age				
Median (IQR)	65 (45 80)	75 (63 82)	65 (45 80)	75 (64 83)
Mean	61.37	70.86	61.44	71.53
Men, *n* (%)	6221 (45.19)	1231 (52.67)	6309 (44.15)	1326 (54.50)
Ethnic group, *n* (%)				
White	11881 (86.31)	2062 (88.24)	11444 (80.08)	2038 (83.76)
Black African and Caribbean	85 (0.62)	28 (1.2)	70 (0.49)	29 (1.19)
Asian	132 (0.96)	38 (1.63)	106 (0.74)	28 (1.15)
Not categorized	1667 (12.11)	209 (8.94)	2670 (18.68)	338 (13.89)
Admission type, *n* (%)				
Emergency	10608 (77.07)	1970 (84.30)	11061 (77.4)	2072 (85.16)
Elective	3157 (22.93)	367 (15.7)	3229 (22.6)	361(14.84)
ITU during admission, *n* (%)	301 (2.19)	73 (3.12)	329 (2.30)	69 (2.84)
HRG, *n* (%)				
A (Nervous system, pain management)	910 (6.61)	146 (6.24)	997 (6.98)	157 (6.45)
B (Eyes and periorbital)	47 (0.34)	5 (0.21)	67 (0.47)	9 (0.37)
C (Mouth, head, neck, ears)	587 (4.26)	61 (2.61)	527 (3.69)	57 (2.34)
D (Thoracic)	1472 (10.69)	303 (12.97)	1415 (9.9)	287 (11.8)
E (Cardiac)	1919 (13.94)	415 (17.76)	2152 (15.06)	423 (17.39)
F (Digestive system)	2093 (15.21)	303 (12.97)	2098 (14.68)	294 (12.08)
G (Hepatobiliary and pancreatic system)	476 (3.46)	60 (2.57)	509 (3.56)	74 (3.04)
H (Orthopaedic)	2022 (14.69)	227 (9.71)	1934 (13.53)	269 (11.06)
J (Skin)	346 (2.51)	52 (2.23)	357 (2.50)	80 (3.29)
K (Endocrine system)	151 (1.1)	156 (6.68)	162 (1.13)	148 (6.08)
L (Renal, urological, male reproductive system)	1034 (7.51)	252 (10.78)	1147 (8.03)	230 (9.45)
M (Female reproductive system)	705 (5.12)	30 (1.28)	728 (5.09)	47 (1.93)
N (Obstetric)	91 (0.66)	1 (0.04)	113 (0.79)	1 (0.04)
P (Paediatric)	166 (1.21)	15 (0.64)	178 (1.25)	6 (0.25)
Q (Vascular)	183 (1.33)	82 (3.51)	125 (0.87)	56 (2.3)
R (Diagnostic imaging)	46 (0.33)	15 (0.64)	70 (0.49)	15 (0.62)
S (Haematological, chemotherapy, radiotherapy, specialist palliative care)	288 (2.09)	32 (1.37)	305 (2.13)	34 (1.4)
U (Undefined groups)	1 (0.01)	0	10 (0.07)	0
V (Trauma, emergency medicine, rehabilitation)	97 (0.7)	8 (0.34)	113 (0.79)	31 (1.27)
W (Immunology, infectious diseases, other healthcare contacts)	1131 (8.22)	174 (7.45)	1283 (8.98)	215 (8.83)
IMD, *n* (%)				
0 (most deprived)	2871 (20.97)	590 (25.43)	2911 (20.53)	640 (26.45)
1	2871 (20.97)	478 (20.60)	2840 (20.03)	518 (21.40)
2	2766 (20.21)	435 (18.75)	2763 (19.49)	475 (19.63)
3	2530 (18.48)	387 (16.68)	2621 (18.49)	404 (16.69)
4 (least deprived)	2650 (19.36)	430 (18.53)	3046 (21.46)	384 (15.83)
Charlson Comorbidity score, *n* (%)				
0	9390 (68.22)	1093 (46.77)	9558 (66.89)	1104 (45.38)
1	1970 (14.31)	445 (19.04)	2126 (14.86)	461 (18.95)
2+	2405 (17.47)	799 (34.19)	2606 (18.24)	868 (35.68)

HRG, Health Resource Group; IMD, index of multiple deprivation; IQR, interquartile range; ITU, intensive therapy unit.

shown in Table 3. The interrupted time series analysis demonstrated a statistically significant (P=0.017) accelera tion in the trend for reducing length of stay in people with diabetes after the intervention; in people without diabetes there was no evidence of any change in trend in the post intervention period (P=0.48). Readmissions for people both with and without diabetes showed a statistically significant increase after the intervention (P<0.001 and P<0.001, respectively; Fig. 1).

The before and after analysis demonstrated a reduction in mortality rates in both those with and without diabetes; however, in the time series analysis, there was no evidence for a difference in mortality in people with diabetes (P=0.305), whereas in those without diabetes there was an apparent increase (P = 0.007; Fig. 1). Detailed time series model findings with explanatory notes are given in Table S1.

Discussion

When considered together, the before and after study and interrupted time series analysis show that the DICE project led to a significant reduction in length of stay for people with diabetes beyond that observed in people without diabetes. The reduction in mortality observed in the before and after

Table 2 Results of the before and after analysis

	People with diabetes 2013	People with diabetes 2014	People without diabetes 2013	People without diabetes 2014
Population	2337	2433	13 765	14 290
Mortality, *n*	152	106	503	436
Mortality rate, %	6.5	4.4	3.7	3.1
Unadjusted mortality odds ratio	0.66 (0.51, 0.85)		0.82 (0.72, 0.93)	
Adjusted* odds ratio (95% CI)	0.63 (0.48, 0.82)		0.81 (0.70, 0.93)	
Median length of stay, days	3.5	3.0	2.0	1.9
Mean length of stay, days	7.5	6.7	5.0	4.7
Unadjusted length of stay relative ratio (95% CI)	0.92 (0.84, 0.99)		0.93 (0.90, 0.96)	
Adjusted* length of stay relative ratio (95% CI)	0.89 (0.83, 0.97)		0.93 (0.90, 0.96)	
30 day readmissions, *n*	401	389	1614	1693
Readmission rate, %	17.2	16.0	11.7	11.9
Unadjusted readmission odds ratio (95% CI)	0.92 (0.79, 1.07)		1.02 (0.94, 1.09)	
Adjusted* readmission odds ratio (95% CI)	0.96 (0.82, 1.12)		1.04 (0.96, 1.12)	

*Adjusted for age, sex, ethnic group, IMD quintile, healthcare resource group category, intensive therapy unit episode, modified Charlson comorbidity score, and emergency/elective admission.

Table 3 Baseline characteristics of individuals included in the interrupted time series analysis

	2008		2009		2010	
	Non diabetes	Diabetes	Non diabetes	Diabetes	Non diabetes	Diabetes
Population, *n*	27 360	3724	29 437	3982	29 644	4491
Men, *n* (%)	12 152 (44.42)	2064 (55.4)	13 146 (44.7)	2038 (51.2)	13 000 (43.9)	2339 (52.1)
Age						
Mean (SD)	61.2 (21)	71.0 (14.6)	60.65 (21.5)	70.6 (15.4)	61.2 (21.5)	70.7 (15.7)
Median (IQR)	64 (25, 79)	74 (63, 81)	64 (44, 79)	73 (63, 81)	65 (45, 79)	74 (63, 82)
	2011		2012		2013	
	Non diabetes	Diabetes	Non diabetes	Diabetes	Non diabetes	Diabetes
Population, *n*	27 338	4266	26 551	4363	27 712	4646
Men, *n* (%)	12 203 (44.64)	2252 (52.8)	11 764 (44.31)	2370 (54.3)	12 656 (45.67)	2445 (52.63)
Age						
Mean (SD)	61.5 (21.5)	70.7 (15.4)	61.3 (21.6)	70.7 (15.6)	61.6 (21.6)	71.1 (15.6)
Median (IQR)	65 (45, 80)	74 (62, 82)	65 (45, 80)	74 (63, 82)	65 (45, 80)	75 (63, 82)
	2014		2015		2016*	
	Non diabetes	Diabetes	Non diabetes	Diabetes	Non diabetes	Diabetes
Population, *n*	28 929	5111	30483	5665	13159	2343
Men, *n* (%)	12 889 (44.5)	2772 (54.24)	13 860 (45.5)	3089 (54.53)	1250 (53.35)	5951 (45.2)
Age						
Mean (SD)	61.9 (21.8)	71.9 (15.2)	62.7 (21.6)	72.2 (14.8)	61.9 (21.7)	71.4 (15.7)
Median (IQR)	66 (45, 80)	75 (65, 83)	67 (47, 81)	75 (65, 83)	66 (46, 80)	74 (63, 83)

IQR, interquartile range. *6 months of data included (January to June).

analysis was not seen in the interrupted time series analysis. Notably, in the interrupted time series analysis, mortality increased in those without diabetes in contrast to those with diabetes. Readmissions, as expected, were significantly higher in people with diabetes than in those without diabetes, although lower than reported in other studies [23]. After the intervention, readmissions continued to increase in parallel with inpatients without diabetes.

Diabetes presents a significant burden for inpatient services, and people with diabetes have higher inpatient mortality, morbidity and hospital acquired complication rates, longer length of stay and higher readmission rates [12,24].

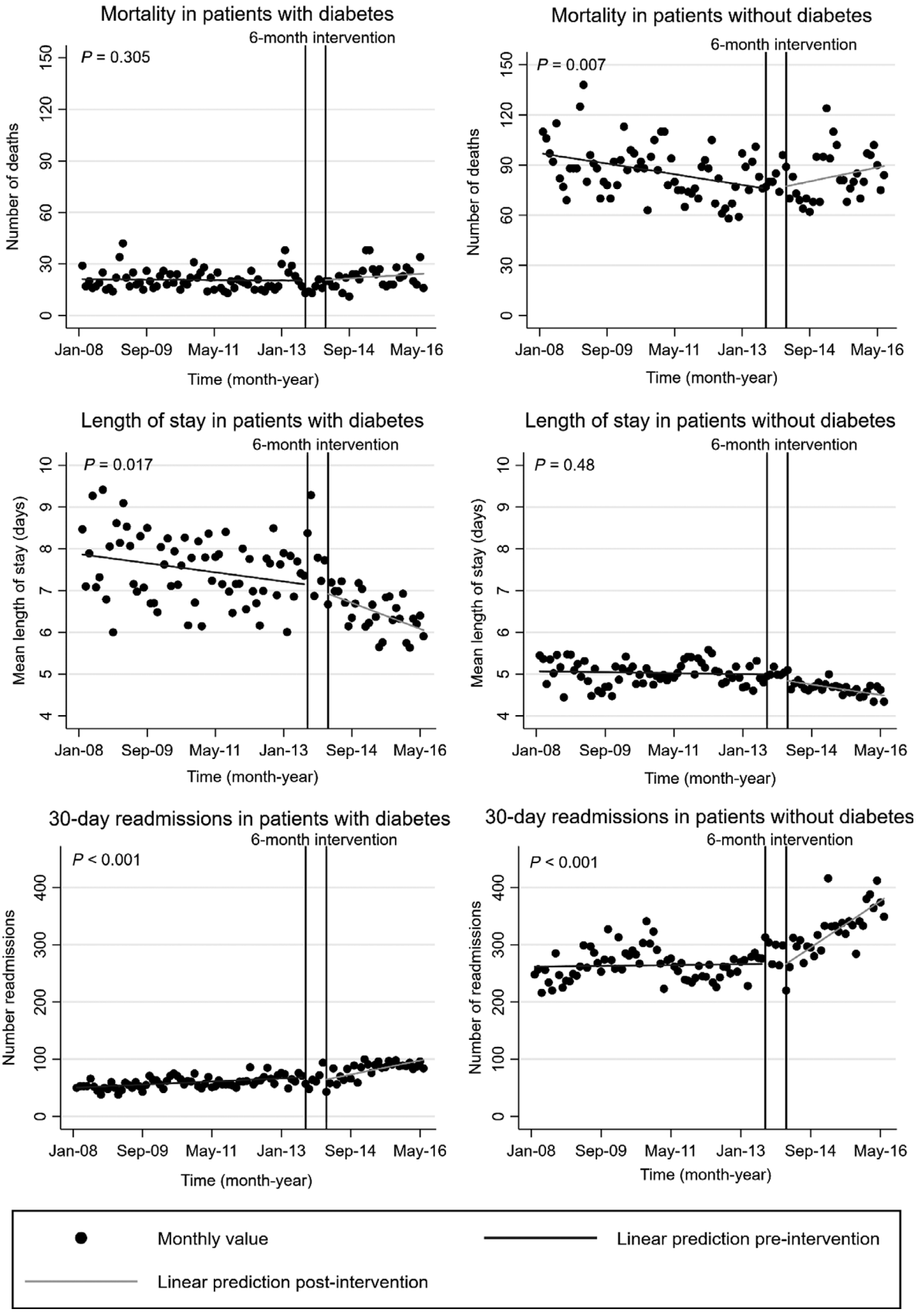

FIGURE 1 Interrupted time series analysis 2008 2016.

As well as the obvious benefits to people with diabetes, improvement in these outcomes could have very significant financial benefits. A limited number of studies suggest that the presence of diabetes teams reduces length of stay, but these studies are historic and relate to a time when length of stay was considerably longer than today. The impact of diabetes inpatient teams on readmission rates has been evaluated in studies, with differing outcomes reported [23,25]. One such study found reduced 30 day readmissions in people admitted to medical services, while readmissions to surgical services increased [26]; in the present study, only a relatively small proportion of the inpatients with diabetes was included in the intervention, in contrast to the present study, which impacted the whole diabetes inpatient population and additionally factored in the changes in the length of stay and readmissions of those without diabetes into the analyses.

The present study is the first to evaluate the effect of a whole systems approach to inpatient diabetes care on length of stay, mortality and readmissions across all medical and surgical adult wards in an acute general hospital. A key element of the DICE programme was the involvement of all members of the diabetes team in the design and implementation of novel interventions aimed at delivering rapid, evidence based, high quality care and education of non specialist healthcare staff. Unlike other studies, it is unique in that it uses interrupted time series analysis to adjust for changes in the background population.

The results of the interrupted time series analysis highlight the limitations of the before and after study design, which is widely used to assess the impact of healthcare interventions. The before and after analysis indicated a significant reduction in length of stay and mortality, which was greater in people with diabetes than in those without; however, in the interrupted time series analysis, while reduction in length of stay remained significant and was shown to be attributable to implementation of the DICE project, the reduction in mortality was not. In the case of mortality, using the 6 month pre intervention group alone as a control would have produced a false positive result. Furthermore, the interrupted time series analysis revealed a wider issue of increasing 30 day readmissions in all patients, indicating the presence of systemic factors, outside of the DICE project, influencing readmissions to the hospital.

Previous studies have reported a median reduction in length of stay of 3 days when employing a diabetes inpatient specialist nurse for inpatient care [16]; however, the most recent of these was conducted in 2008 and, with changes in practice, stretched resources and pressures on hospital beds, it is not clear whether similar improvements would be seen today. The results of the present analysis showed a more modest, but significant and ongoing, reduction in length of stay. With 1 bed day estimated to cost the NHS £400 this sustained reduction in length of stay will have saved the trust over £2 m in the 3 years since the DICE project was implemented [27].

Few studies have employed the quasi experimental methodology of interrupted time series analysis to assess the impact of care interventions in the clinical setting, with before and after analysis being the more widely used method [18]. This is the first study to use interrupted time series analysis to examine length of stay, readmission and mortality after implementation of a whole systems approach to inpatient diabetes care; however, interrupted time series analysis is gaining favour and has been used to assess the impact and successful implementation of national guidance [28].

In the present analysis two analytical methodologies were combined to address the limitations associated with using before and after analysis in isolation, and to account for unknown confounders outside the intervention which might affect the observed outcomes. The study used routinely collected data taken from inpatient medical records; this captures patients' hospital stay and the majority of information and clinical codes are therefore well recorded. It is possible, however, that recording of some comorbidities might be incomplete. Furthermore, the intervention and analysis are based on data from a single hospital trust; it is therefore not clear whether the results would be generalizable to other hospitals. Finally, being a multi systems approach it is not possible to determine which of the multiple interventions had the greatest impact on patient outcomes, nevertheless it is unlikely that any of the interventions would be detrimental to diabetes care.

In conclusion, the DICE project showed that a well staffed inpatient team, delivering care through a whole systems approach and weekend working led to a sustained reduction in length of stay for inpatients with diabetes, which has important financial implications. With multiple factors influencing patient length of stay and mortality in the inpatient setting, the methodology used in the present study shows the additional information that can be gained by using interrupted time series analysis, and highlights the benefit of using a negative control group comprising patients without a diagnosis of diabetes. The authors of the present study advocate the use of this quasi experimental methodology for assessing the impact of interventions in the clinical setting.

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Competing interests

None declared.

Ethical approval

The study was approved by the Medical Ethics Committee of [INSTITUTION], and informed consent was obtained from all participants. This research study was conducted in accordance with the guidelines of the Declaration of Helsinki.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Appendix S1. The DICE programme.
Appendix S2. Methods..
Figure S1. DICE chart illustration of insulin profiles.
Figure S2. DICE chart illustration of hyperglycaemia treatment algorithm.
Figure S3. DICE chart illustration of bedtime snack sticker.
Table S1. Results of the ITS analysis.

CHAPTER 3

Chapter 3: Impact of diabetes specialist nurses on inpatient care: a systematic review

The concept for the systematic review was determined by me as the primary researcher and I carried out initial scoping on the topic of diabetes inpatient specialist nurses and subsequently defined the research question. From this I designed the review, determining the parameters and creating relevant search terms from previous similar studies, ensuring the Boelean terms being used were inclusive. The data extraction and initial selection of papers from the titles and abstracts for both the primary and secondary extraction were carried out by me as the primary researcher. Selection of papers and data extraction was carried out independently by myself and a secondary researcher on the fully obtained text. From this, I interpreted the data and wrote the review.

Impact of diabetes specialist nurses on inpatient care: a systematic review

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Contributions:

The review was conducted primarily by Dr F Akiboye with Dr H Sihre acting as a second reviewer independently selecting abstracts for inclusion against eligibility criteria, validating chosen papers and discussion of the final critical appraisal. Miss M Al Mulhem acted as a second reviewer to select papers and quality assess papers from the second data extraction and independently extract data from the selected papers. Dr N Adderley supported writing the paper. Dr K Nirantharakumar and Professor G Rayman helped inform the scope of the review with Professor Rayman providing expert opinion in the field of inpatient diabetes. All authors reviewed and approved the final manuscript.

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Abstract

Background: People with diabetes have longer hospital stays and poorer clinical outcomes. Diabetes inpatient specialist nurses have been introduced to improve care.

Aims: To assess the evidence for the benefit of diabetes specialist nurses in the inpatient setting.

Methods: A systematic search of MEDLINE (ovid), Embase (ovid), CINAHL (EBSCO) and Web of Science core collection from January 1998 to September 2019 was performed using key terms for diabetes specialist nurses and hospital setting. Studies measuring patient care using any standardised or validated outcome measures, after introduction of a dedicated diabetes specialist nurse or nursing team were eligible for inclusion and findings reported by narrative synthesis.

Results: There were 10 studies which met the inclusion criteria. One was a randomised controlled study and the remaining 9 studies were before and after studies with 3 of them using a time series analysis methodology. The majority reported length of stay (LOS) and showed a reduction in median LOS by between 0.5 and 3 days. Reductions in bed occupancy ranged from 39 to 47%. There was a paucity of evidence for outcomes related to patient care with some measures limited to single studies. These included a 52% reduction in total drug errors, improved patient knowledge, higher patient satisfaction and improved glycaemic control post discharge. There was no reduction of mortality observed.

Conclusions: These studies suggest a reduction in length of stay and improved clinical care for patients with diabetes after the introduction of diabetes inpatient specialist nurses. Future research should examine a range of benefits associated with diabetes inpatient specialist nurse delivered services, including reduction of inpatient complications such as infections and cardiovascular events.

Trial registration

This review was registered on the PROSPERO database on 11/10/2017, registration number CRD42017076478.

Introduction

The incidence of diabetes continues to rise with the International Diabetes Federation predicting its prevalence will reach 9.9% globally by 2030 (1). People with diabetes tend to have longer length of stay and are at greater risk of complications, often associated with hyperglycaemia (2).The National Diabetes Inpatient Audit (NaDIA) in 2019 showed that patients with diabetes account for 18% of bed occupancy, an increase from 14% in 2010 (3). For the majority of patients diabetes is a secondary diagnosis rather than the primary cause for admission, therefore patients are more commonly under the care of non-diabetes specialists. The training doctors on these teams report lack of further education in diabetes after qualifying with only 28% feeling fully confident in managing diabetes (4)The delivery of care to patients with diabetes, as with a number of other specialities, has moved towards specialist nurses and nursing teams. They provide support and education for staff and patients across specialities and often provide phone or clinic contact to avoid hospital admission or facilitate discharge of patients in a timely fashion. The need for diabetes inpatient specialist nurses (DISNs) has been stated repeatedly and the economic case for their presence has been published by NHS diabetes in 2012 in a report titled “Specialist diabetes inpatient nurses cost-effectively improve care” (5; 6; 7). Despite strong endorsements, including a 2003 statement from the Department of Health (DH) highlighting the importance of effective care for inpatients with diabetes, and a 2011 National Institute of Clinical Excellence (NICE) quality measure, advising at least one diabetes specialist nurse with an inpatient focus per 300 beds, DISNs are not ubiquitous (8; 9). NaDIA 2018 showed that 22% of hospitals still do not have a dedicated DISN (10).

There are no previous systematic reviews assessing the impact of diabetes specialist nurses in the inpatient setting. A Cochrane review in 2003 by Loveman *et al.* examined the role of diabetes specialist nurses focused predominantly on the community setting and did not find their introduction to be superior to standard care for improving care overall (11). The impact of specialist nurses for all specialities has been assessed in the context of the changing work force and nurses work patterns in a Cochrane review by Butler et al in 2011 (12). This review of randomised controlled trials looked at any objective measure of patient or staff outcome and found that the introduction of specialist nurses reduced length of stay and the development of pressure ulcers in hospital. Whilst this review selected from a range of specialist areas, there was only one study included that was specific to diabetes (13). On introducing diabetes specialist nurses, many trusts encouraged their teams to document their activity and their effectiveness. Consequently, there are a number of ‘before and after

studies' looking at the effectiveness of diabetes specialist nurses that have not been assessed systematically. A recent hermeneutic review conducted by Lawler et al (14) explores the scope of diabetes specialist nurses' role, both in the community and hospital. It provides a favourable appraisal of the literature for the effectiveness of diabetes specialist nurses in terms of reduced patients harms, educational value and continuity of care. This review however was not conducted systematically and did not include an appraisal of the quality of the evidence. While this phenomenological approach provides a broad and rich view of the range and impact of specialist nurses, it is subject to reviewer bias in study selection.

Therefore, we conducted a systematic review with the aim of examining the existing evidence on the impact of diabetes inpatient nurses on patient and staff outcomes and to highlight areas for further research.

Objectives

This review aims to look at the measured impact of introducing a DISN or dedicated diabetes inpatient nursing team on hospitalised adult inpatients with diabetes. For this assessment of impact a measured comparison of the service, patient outcomes, knowledge or ability of patients with diabetes before and after the introduction of the DISN(s) could be included.

Methods

The review was conducted in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA-P) guidelines.

Registration

A protocol for this systematic review is registered on PROSPERO 11/10/2017 (registration: CRD42017076478).

Study design

All relevant published studies from 1st January 1998 to 1st September 2019 were sought for inclusion in this study as recent decades have seen a movement towards promoting DISNs in the literature and national guidance (13; 15). There was no restriction on the study design selected for inclusion, therefore randomised controlled trials (RCTs), quasi-experimental studies and observational studies, including before and after studies and interrupted time series analysis studies were included. There was no language restriction applied during the search.

Participants

The study participants were hospital inpatients with type 1 or type 2 diabetes mellitus. The hospitals include acute and non-acute hospitals ranging from small to large in size. Both public and private and teaching and non–teaching organisations were included.

Interventions

Studies that involved the introduction or addition of one or more dedicated diabetes inpatient specialist nurse (DISN), nurse prescriber, nurse educator or other equivalent terms used internationally, were included. In focusing on reviewing the impact of new or additional DISNs, this review does not examine the specific tasks undertaken by nurses in

their role. Studies extending the scope of an existing outpatient nurse to inpatient work or an inpatient team to provide an outpatient service or outreach service of in-post DISNs to the emergency department were excluded. These were deemed more of an evaluation service delivery, which is beyond the scope of this review. In a similar manner those studies upskilling an existing inpatient specialist nurse in post, for example with prescribing training, were not included. Studies substituting physician for a specialist nurse were also excluded.

Outcomes measures

This review examined any objective measures of patient outcomes including mortality, in-hospital death, length of stay, and readmission. Also of interest were objectively measured "nursing sensitive patient outcomes'', defined by Doran (2003) as those that are "relevant, based on nurses' scope and domain of practice, and for which there is empirical evidence linking nursing inputs and interventions to the outcomes" (16). Examples include infections, falls, pressure ulcers, cardiovascular events, hypoglycaemia rates or medication errors. Objective measures of patient satisfaction, quality of life and disease impact were only included in this review if they used a validated tool, such as the Diabetes Treatment Satisfaction Questionnaire for inpatients (DTSQ-IP) (17).

Search method for identification of studies

A search was conducted in MEDLINE (ovid), Embase (ovid), CINAHL (EBSCO) and Web of Science core collection from 1st January 1998 to 30 September 2019. The search strategy used exploded MeSH terms for variants of combinations of relevant keywords, including study population: "inpatients" OR "hospital" AND "diabetes mellitus", AND intervention: "specialist nurse". The MEDLINE search strategy is shown in supplementary table 1 and was adapted to the syntax of the aforementioned databases.

In addition, reference lists of all included papers and relevant literature such as position statements were screened to identify any further publications.

Data collection and analysis

Titles and abstracts were screened by the primary reviewer (FA) for relevance to the population and intervention. The full articles for potentially relevant papers were then obtained. Full texts of obtained articles were read independently by two reviewers, FA and HS or MAM, and included if they fulfilled all of the following 5 pre-established criteria:

1. an original study published in full;
2. participants were patients with diabetes (type 1 or 2);
3. it was hospital-based;
4. the intervention involved a new or additional diabetes inpatient specialist nurse;
5. the outcomes were formal extraction or collection of any objective or standardised data from or relating to participating patients.

Studies that could not be accessed in full (such as conference abstracts) were excluded, as there was insufficient detail to determine whether they met the inclusion and exclusion criteria. Where the full article was available, but insufficient information was available to

determine whether the study was eligible for inclusion, the authors were contacted to clarify whether the study fulfilled the inclusion criteria. We included studies that provided any widely accepted measures, quantitative data and standardised or validated questionnaires. Any disagreement was discussed and where necessary resolved in collaboration with a third independent reviewer (KN).

Data extraction was carried out independently by the primary reviewer (FA) and a second reviewer (MAM) using forms developed for the study (after piloting the forms in two contrasting, included studies (18; 19). The data collected included the study design, setting, study baseline and follow-up period, sample size, patient population studied and whether the changes in the background patient population (without diabetes) were also measured. For each study, any objective variable was recorded as a primary outcomes with the validated or modified assessments recorded as secondary outcomes. An example data collection sheet is shown in appendix 1.

Quality assessment

All studies were assessed for risk of bias using the relevant tool according to study design. The Cochrane RCT risk of bias tool was used for randomised controlled trials and the NIH National Heart Lung and Blood Institute Quality Assessment Tool for Before-After (Pre-Post) Studies, including interrupted time series analysis (20; 21)

Data analysis

The extracted data comprising measured changes and effect sizes from included studies was analysed in the broader context of the field, with exploration of the relationships between the data. A preliminary tabulated analysis is presented as well as a more detailed narrative synthesis. A meta-analysis was not conducted as the number of studies with overlapping outcomes was limited.

Results

Results of the search

The initial search extracted on 1st May 2017 identified 8464 unique studies and a further 1209 in the second search. The full articles for 47 potentially relevant studies were obtained and assessed independently by the two reviewers. Of the total 47 articles, 10 met the inclusion criteria for final inclusion in the study. Study selection is summarised in the flow diagram in figure 1.

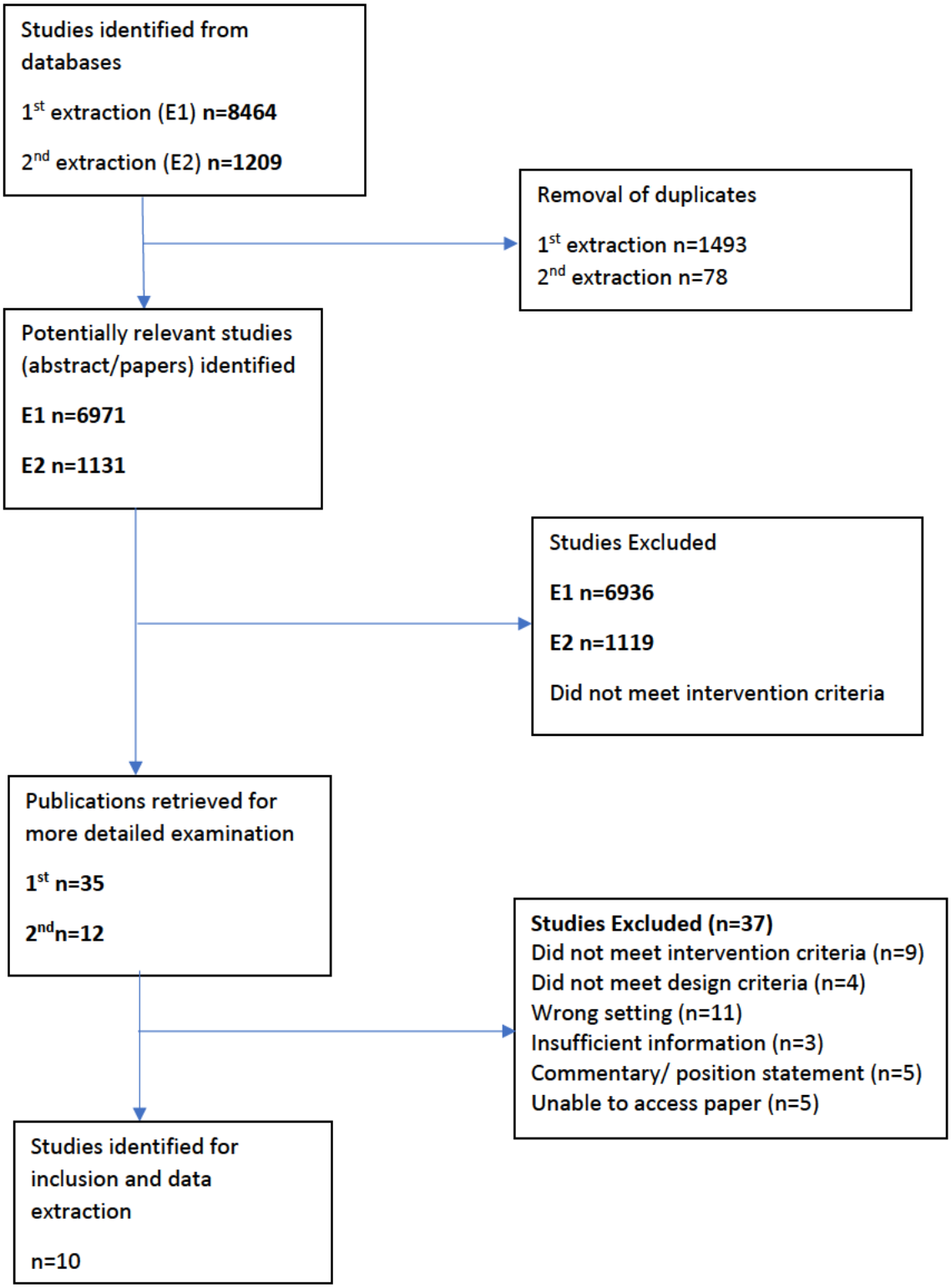

FIGURE 1. FLOW DIAGRAM FOR STUDY SELECTION

Description of included studies

Of the 10 studies included there was one prospective randomised controlled trial by Davies et al. (18) and two controlled cohort studies by Cavan et al and Gardiner et al (22; 23). The remaining seven studies were before and after cohort studies (19; 24; 25; 26; 27; 28; 29). The Pledger, Sampson and Akiboye studies (19; 29; 24) incorporated time series design in the methodology with sequential measurements over the study duration.

Sample size varied from under 30 patients in each arm, in the Carey study (26), to around 25,000 in the Cavan study (22). The follow-up period ranged from 3 months in the Carey and Courtenay (26; 25) studies to 5 years in the Flanagan study (27) and is summarised for included studies in table 1.

All of the studies looked at patients over a range of disciplines specifying either inclusion of patients from medicine and surgery or that participant inclusion was "unselected". While all 9 before and after studies were looking at patients with diabetes, six of them additionally examined the background population without diabetes to account for trends of confounders in the hospital population (29; 19; 22; 27; 28; 24).

Notably, the Courtenay (25) and Carey (26) papers were conducted in the same trust over the same time period and the Carey paper appears to be a subgroup analysis using the same data; the results of the small Carey study are therefore only considered where the authors reported additional outcomes to the Courtenay study.

The aim for all included studies was to determine the impact of one or more DISNs on a range of patient outcomes within a service. As any objectively measured or standardised outcome could be included, all are reported. The primary stated outcome for each study is indicated in table 2.

Table 1. Baseline characteristics of included studies

Study	**Design**	**Hospital type**	**Number of additional DISNs (WTE)**	**Sample size**	**Patient population**	**Follow-up duration**	**Background population assessed**
Davies 2001 (18)	Prospective RCT	University hospital	1	152 148	Medical and surgical referrals	One year post discharge	NA
Cavan 2001 (22)	Controlled cohort study	District general	1	24323 24365	Medical and surgical	1 year 1 year	yes

Pledger 2005 (19)	Before and after/ time series analysis	District general	0.85 WTE	Not disclosed Not disclosed	Unselected referrals	7/12 6/12…	yes
Sampson 2006 (24)	Before and after/ time series analysis	University hospital	1	14722	Medical and surgical	4 years 2 years	yes
Courtenay 2007 (25)	Before and after	District general	1	187 265	Med and surgical patients with DM on treatment	3/12 3/12	No
Carey 2008 (26)	Before and after	District general	1	27 29	Med and surgical patients with DM on treatment	3/12 3/12	N/A
Flanagan 2008 (27)	Before and after	Large teaching 1200 bed	5	3903 24031	Medical and surgical patients	1 year 5 years	yes
Gardiner 2018 (23)	Prospective cohort study	Large teaching hospital	2 (1 DISN and 1 educator)	35 32	Patients referred to DM service with poor glycaemic control	Baseline and 3/12 post discharge 12/12 study	N/A
Mandel 2019 (28)	Before and after	Medical and surgical	2 (1 practitioner, 1 educator)	850	Medical and surgical patients	1/12 1/12	yes
Akiboye 2019 (29)	Before and after/ time series analysis	District general	2.5 (increase of 1.5 WTE)	2337 2433	Medical and surgical patients	6 /12 B&A 6 yrs 2.5 yrs	yes

WTE= whole time equivalents

Table 2. Primary outcomes across the reported studies

Study	Length of stay	Excess length of stay	Bed occupancy	Readmission	Insulin errors	Oral hypoglycaemic agent errors	Mortality	Mean blood glucose
Davies 2001	↓			↔				
Cavan 2001	↓		↓					
Pledger 2005	↓		↓					
Sampson 2006		↓						
Courtenay 2007	↓				↓	↓		
Carey 2008	↔				↓	↓		
Flanagan 2008	↓		↓					
Gardiner 2017								↓
Mandel 2017	↓			↓				
Akiboye 2019	↓			↔			↔	

Quality of the evidence and risk of bias in included studies

All of the studies included, other than the one randomised controlled study (18), were observational studies using either administrative data or data collected by the DISNs. The quality of the evidence in the identified studies was therefore mixed.

The single RCT (Davies 2001) was assessed using the Cochrane risk of bias tool for randomised controlled trials and was assessed to be of fair quality with unclear bias due to insufficient information in the categories of random sequence generation and allocation concealment.

Using the NIIR quality assessment tool, the Sampson 2006, Courtenay 2007, Carey 2008, Flanagan 2008, and Akiboye 2019 studies were assessed as having a low risk of bias (24; 25; 26; 27; 29). The studies by Cavan 2001, Pledger 2005, Gardiner 2018 and Mandel 2019 (22; 19; 23; 28) were assessed to be of moderate risk of bias, as detailed in table 3. The studies are arranged by year of publication and the quality is generally higher in the more recent studies. Pledger is the weakest study with the number of participants not disclosed and a lack of clarity around several other categories which were not reported particularly around the selection and eligibility of participants (19), but on further discussion it was included in the review as a visual representation of the outcome is presented, which was taken into account in this report. However, unlike all other studies the objectives are not clearly stated.

Selection bias was reduced in most studies by including all patients with diabetes in certain clinical areas. The review design for reporting on objective and validated criteria was corroborated by all studies fulfilling this component of the quality assessment tool. It was difficult to tell in all except the Akiboye 2019 study (29), whether the researchers were blind to the intervention.

Table 3. Risk of bias assessment using NIH quality assessment tool for before and after (pre-post) studies with no control group.

	Was the study question or objective clearly stated	Were eligibility/selection criteria for the study population prespecified and clearly described?	Were the participants in the study representative of those who would be eligible for intervention in the general or clinical population of interest?	Were all eligible participant that met the pre-specified entry criteria enrolled?	Was the sample size sufficiently large to provide confidence in the findings?	Was the intervention clearly described and delivered consistently across the study population?	Were the outcome measures prespecified, clearly defined, valid and reliable assessed consistently across all study participants?	Were the people assessing the outcomes blinded to the participants' interventions?	Was the loss to follow-up after baseline 20% or less? were those lost to follow-up accounted for in the analysis?	Did the statistical methods examine changes in outcome measures from before to after the intervention? Were statistical tests done that provided p values for the pre-to-post changes?	Were outcome measures of interest taken multiple times before the intervention and multiple times after the intervention (i.e. did they use an interrupted time-series design?)	If the intervention was conducted at a group level (e.g. a whole hospital) did the statistical analysis take into account the issue of individual level data to determine effects at the group level?	Overall quality of study
Cavan 2001	●	○	●	●	●	●	●	●	○	●	●	●	fair
Pledger 2005	●	●	●	●	○	●	●	●	○	○	●	●	fair
Sampson 2006	●	●	●	●	●	●	●	●	●	●	●	●	good
Courtenay 2007	●	●	●	●	●	●	●	●	●	●	●	●	good
Carey 2008	●	●	●	●	●	●	●	●	●	●	●	●	good
Flanagan 2008	●	●	●	●	●	●	●	●	○	●	●	●	good
Gardiner 2017	●	●	●	●	●	●	●	●	●	●	●	●	fair
Mandel 2017	●	●	●	●	●	●	●	○	●	●	●	●	fair
Akiboye 2019	●	●	●	●	●	●	●	●	●	●	●	●	good

NR = not recorded, CD = can't decide, NA = not applicable.

● = yes, ● = can't decide, ● = no, ● = not applicable, ○ = not recorded.

Outcomes

The range of outcomes reported was narrow and generally focused on length of stay, measured as mean or median, or bed occupancy as this would translate into savings for the trust employing the DISN. A summary of the outcomes is displayed in table 2.

A measure of length of stay was reported in all studies except Gardiner 2018, with the Sampson paper reporting this as excess LOS above the population without diabetes (23; 24). The studies varied in their methods for calculating length of stay with some reporting length of stay as a mean while others reported a median LOS. Bed occupancy as a percentage of patients in hospital beds with diabetes was expressed with differing timeframes and was evaluated in the studies by Cavan, Pledger and Flanagan (22; 19; 27), while the effect on readmissions was assessed in the studies by Davies, Mandel and Akiboye (18; 28; 29).

The Courtenay and Carey papers examined oral hypoglycaemic and insulin errors, with the Courtenay study providing detailed subgroup analysis of the drug errors noted in the Carey study (25; 26). The Gardiner study (23) reported change in mean blood glucose and HbA1c three months following discharge and one study additionally reported inpatient mortality as an outcome measure (Akiboye) (29).

The majority of secondary outcomes were reported in the comprehensive Davies study (18), which used validated and modified established questionnaires to measure diabetes related QOL, diabetes knowledge and patient satisfaction. The authors also sought to determine if the improvement in hospital care impacted negatively on use of community resources.

Length of stay and bed occupancy

The length of stay measured at baseline, prior to introduction of the DSNs varied widely across studies from 7.5 (Akiboye 2019) to 9.8 (Pledger 2005) for mean measurements (29; 19) and 3.5 (Akiboye 2019) to 17.5 days (Carey 2008) for median LOS (29; 26). There was a significant reduction seen in length of stay in all except the Carey study which reported a median 3 day reduction that was not statistically significant. The median reduction in LOS reported ranged from a 0.5 to 3 day difference before and after the intervention. Those reporting a mean LOS (Pledger 2005, Flanagan 2008, Akiboye 2019) describe a smaller difference of 0.5 -1.1 days (19; 27; 29).

The three studies reporting bed occupancy (Cavan 2001, Pledger 2005, Flanagan 2008) had a larger number of participants and reported significant and sizable reductions of 36-47% (22; 27; 19).

Readmissions

Three studies measured readmissions by various methods (Davies, Mandel, Akiboye) (18; 28; 29). Mandel and Akiboye reported 30-day readmission rate (Mandel, Akiboye) (28; 29).

The Davies study measured mean time to readmission in days while the Akiboye study also conducted an interrupted time series analysis of 30-day readmission rates over an 8-year period. There was no statistically significant impact on hospital readmissions on introduction of a diabetes specialist nurse in any of the studies over the short term.

Drug errors

Two published studies looked at drug errors, however they were carried out in the same trust over the same period with Carey effectively a sub-group study of the Courtenay study providing more detailed drug error information. Drug errors were significantly reduced in the Courtenay 2007 and Carey 2008 studies (26; 25). Courtenay reported an overall 52.1% reduction in drug errors, while Carey specified these a 50% reduction in insulin errors and 74.5% reduction in oral hypoglycaemic agent errors (74.5%) (26; 25).

Mean glucose

Gardiner reported statistically significant reductions in mean glucose from 13.3 mmol/l to 11.2 mmol/L ($p = <0.05$) and HbA1c from 10.45% to 8.96% ($p = <0.05$) following inpatient nurse education (23).

Mortality

There was one study reporting mortality (29), which measured mortality with both before and after study and interrupted time series (29). The 6-month period before and after implementation of DISN showed lower mortality following the intervention in those with diabetes OR 0.63 (0.48, 0.82). In the interrupted time series analysis this was found to be a secular trend that cannot be attributable to the intervention with the reduction being not statistically significant in those with diabetes ($p=0.305$) (29).

Miscellaneous outcomes

The findings of Davies' study relating to quality of patient care are reported below.

Quality of life

The Audit of Diabetes Dependent Quality of Life (ADDQoL) was used to measure diabetes related quality of life and did not demonstrate any differences in quality of life between or within groups at baseline or post-discharge.

Diabetes knowledge

The diabetes knowledge questionnaire was assessed with a modified version of the Diabetes Knowledge Scale accounting for insulin users and non-users. There was a significant improvement in the knowledge score post-admission in the intervention group.

Patient satisfaction

A modified version of the Diabetes Clinic Satisfaction Questionnaire (DCSQ) was administered one week post-discharge to assess patient satisfaction and demonstrated that

91% of patients in the intervention group were satisfied with their DISN delivered care compared with 59% in the control group (p <0.001).

Post discharge outcomes

The Davies study showed a trend towards fewer post discharge referrals to the community diabetes nurse, however this was not statistically significant (18).

Gaps in the literature data

There were no studies looking at inpatient complications or standardised measures of staff satisfaction or knowledge after addition of diabetes inpatient specialist nurses.

Discussion

There is a body of evidence indicating that DISNs reduce length of stay by a median of up to 3 days or mean of 1.14 days. Bed occupancy may be reduced by as much as 47%. It is worth noting that the earlier studies conducted between 2001 and 2006 showed the larger effect sizes when baseline length of stay was longer. Fortunately, this bed day saving does not appear to have a negative impact on readmissions or community referrals.

There is some evidence that the introduction of DISNs reduces the number of drug errors both for insulin and oral hypoglycaemic agents (25; 26). There is also evidence from one study to suggest their input has had a positive effect on inpatient glycaemic control (23). Although these benefits are encouraging National Inpatient Diabetes Audit (NaDIA) does not clearly demonstrate that trusts with inpatient nurses consistently show lower drug errors and rates of dysglycaemia. The presence of DISNs does appear to improve patient knowledge and have a positive effect on patient satisfaction (18). However, the studies concluded that DISNs do not have an impact on quality of life following discharge or on inpatient mortality (18; 29).

Completeness and applicability of evidence

This is a comprehensive review that systematically assesses the impact of DISNs taking into account recent publications. The specialist nurses' activities undertaken in each trust were not differentiated and the majority of studies looked at nurses' impact in both medical and surgical ward settings. As such the findings reported are widely applicable to hospital trusts which still lack a dedicated DISN or where one could expand their existing team with additional DISNs.

The majority of studies looking at bed occupancy or length of stay were published before 2008 when the baseline length of stay was higher than it is currently (18; 22; 25; 17; 19; 27). With the drive to reduce bed occupancy in today's climate, the evidence for the recent length of stay reduction is limited to one study, Akiboye et al (29). While the two methodologies used in this study demonstrate a reduction in length of stay, this reduction is smaller than previous studies. Further analysis on the cost implications at present was beyond the scope of this study and may warrant re-evaluation.

This review did not identify studies evaluating in-hospital complications aside from mortality (29). Two studies in a single trust examined drug errors with significant reductions reported with DISN input in 2007 (25; 26). Today, with an increasing prevalence of diabetes it is not clear whether such a work-load is feasible or sustainable for specialist nurses and it may be that these benefits may be achieved in other ways for example with protocol development and electronic prescribing. The role of the specialist nurse in educating inpatients with diabetes appears to carry important and sustained benefits beyond discharge, which have previously been contested in the inpatient setting (23). This suggests that although the benefits seen in earlier studies such as reduced length of stay may have a smaller effect at present, there are likely other as yet unmeasured benefits to DISN input depending on their activity and assumed roles.

Potential biases in the review process

This study is limited by the small number of studies fulfilling the inclusion criteria, however the search strategy was set up to find all possible studies by limiting the search strategy to the population of interest and intervention of interest.

Four databases were used to locate studies and Web of Science database in particular picked up studies submitted in abstract form to conferences which have less strict criteria than papers published in full. As there has generally been a drive to publish positive findings in peer reviewed journals, the use of this broader database helped reduce publication bias. The use of all objective outcome measures from the studies included enabled a more accurate representation of the impact by including the negative secondary outcomes from studies.

Study limitations

The search criteria were broad in order to maximise the likelihood of searching and including an relevant study. The search strategy was focused on the presence of DISN by using a range of terms, however the list was not exhaustive and may have missed some of the job titles for nurses working in diabetes care, which was measured as 117 in the TREND 2019 audit (30).

The databases searched provided a limited search of grey literature, however Web of Science Core collection searches conference proceedings which were therefore included. In addition, the significant experience, knowledge and active involvement of the authors in this field provided potential papers for evaluation of inclusion.

Due to the small number of studies and restricted range of reported measures, for the outcomes of mortality, mean glucose and drug errors a description of the outcome is taken from a single dataset, limiting its applicability.

Agreements and disagreements with other studies or reviews

It is widely accepted that DISNs reduce LOS and this review adds that significant reductions in LOS can still be seen today despite shorter baseline hospital spells for patients throughout the health service.

Diabetes UK has published a literature review citing many of the included studies in a case for economic change advocating the use of DISNs. For this analysis the bed occupancy cost of diabetes is a dominant part of the analysis. Length of stay/ bed occupancy was therefore a primary outcome of many of the papers that contributed to the evidence. While their findings agree with those of this systematic review; the economic case does not examine the quality of the evidence prior to drawing conclusions, and with the addition of a more recent study, the current cost implications may benefit from further evaluation, given the additional benefit in terms of savings from reduced LOS may be limited (29).

The hermeneutic review conducted by Lawler et al draws on some of the same evidence to conclude that diabetes specialist nurses are cost effective and improve patient care by reducing patient length of stay and reduced inpatient harms (drug errors) (14). It also describes the diabetes specialist nurses roles as staff and patient educators as well as providing direct patient care. The efficiency and extent to which diabetes inpatient specialist nurses engage with these various roles will undoubtedly vary between hospitals and even areas within the same trust with differing outcomes. Such differentiation is beyond the scope of this and the Lawler review, however we note that the roles undertaken and outcomes produced by the diabetes specialist nurse are linked and further examination of the most effective activities of the specialist nurse could be usefully examined as a focus in future studies to help guide their key activities. Lawler et al did note that in the outpatient setting patient satisfaction was increased with the presence of diabetes specialist nurses and suggested it was due to time spent with the nurse and continuity of care (14). With the national trend towards shorter inpatient length of stay it is not clear whether the rising trend in readmissions observed in one study along with pressures on the DISN workforce are now having a negative impact on patient satisfaction documented in the Davies study of 2001. The hermeneutic review also offers a note of caution that the stretched diabetes inpatient nursing workforce will not sustain current levels of care for the projected growth in prevalence of diabetes (14). There is a concern that their presence has deskilled and reduced the confidence of non-specialist staff.

This systematic review, whilst drawing similar conclusions to existing reviews and statements tempers the interpretation of the results that has informed these recommendations due to the small number of studies and mixed quality of evidence available when the previous reviews were written. The more common use of analytical methods such as interrupted time series analysis allows a more informed view than the shorter before and after studies most widely used to examine the introduction of DISNs.

Conclusion

There appears to be ongoing benefit in employing DISNs within the NHS today, however the bed saving implications in recent years are less than previously and depend on the background length of stay within the trust. Future studies looking at the impact of diabetes specialist nurses on in hospital complications, up-to-date measures of patient satisfaction

and staff outcomes are warranted. With the increase in demand for DISNs, we recommend effective education of non-specialist staff and evaluation of such initiatives to ensure inpatient diabetes care is sustainable for the future.

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Appendix 1: Example data collection sheet

Design

Hospital type

Sample size (before and after intervention)

Patient population (medical/ surgical/ unselected)

Follow-up duration

Background population assessed? (are the population without diabetes assessed as a negative control)

Primary outcomes (LOS, Excess LOS, Bed occupancy, re-admission, insulin errors, OHA errors)

- Baseline, change and P-value/ CI

Secondary/ Other outcomes?

Supplement

Table 1

	Medline example search
1	exp Diabetes Mellitus/ MeSH all subheadings
2	IDDM
3	NIDDM
4	1 or 2 or 3
5	Exp nurse*
6	Nurses/ MeSH all subheadings
7	Nursing/ MeSH all subheadings
8	Nurs* adj3 specialist
9	Nurs* adj3 educator
10	Nurs* adj3 practitioner
11	DSN
12	DiSN
13	6 or 7 or 8 or 9 or 10 or 11 or 12
14	exp Hospitals/
15	exp Hospitalization/
16	Hospital*
17	Inpatient*
18	ICU/
19	Intensive care
20	14 or 15 or16 or 17 or 18 or 19
21	4 AND 13 AND 20

CHAPTER 4

Chapter 4: The impact of the Diabetes Inpatient Care and Education (DICE) project on harms and complications

The concept for collection data related to patient complications and harms was the work of a previous researcher involved in DICE, who designed the study as a detailed examination of inpatient care, as a more extended bedside assessment, using a similar structure to the National Diabetes Inpatient Audit. In designing the intervention, the DICE team met regularly during the first period of data collection. The bedside information was collected by the nurses every 48 hours and was inputted into an electronic database. With assistance from the IT department, patients identified using this bedside data were assigned the corresponding pseudonym. As the primary researcher, I extracted this information and determined the reportable outcomes. The common pseudonym with the previously pseudonymised PAS data allowed these datasets to be linked. After linking I was able to carry out analysis, interpret the results and write the manuscript.

The impact of the Diabetes Inpatient Care and Education (DICE) project on harms and complications

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ABSTRACT

Background

The Diabetes Inpatient Care and Education (DICE) programme was implemented in July 2013 as a whole systems approach to managing inpatient diabetes in Ipswich Hospital. It comprised a number of initiatives, including a daily list of new admissions with a diagnosis of diabetes, allowing prompt review and medication adjustment; a daily electronic list of all patients with hypoglycaemia generated from ward glucose meters connected wirelessly to a central server; an online referral system with grading of clinical urgency; a junior doctor's

induction training programme; and a care pathway contained in an eight page booklet which included advice on diabetes management and all relevant treatment charts. The employment of two additional full-time diabetes nurse specialists enabled this service to be delivered seven days a week.

Aim

To evaluate the impact of the DICE project on drug errors, in-hospital complications and severe hyper- and hypoglycaemia.

Method

Complication and drug error data was collected from bedside notes of patients with diabetes admitted in the six months before and after implementation of DICE. Glucose data was extracted from glucose meters for the same time period. A logistic regression model was used to calculate improvement in outcomes adjusting for important covariates.

Results

Insulin and oral agent prescription and management errors were significantly reduced, with the largest reduction in insulin management errors (OR 0.17, 95%CI 0.12-0.24). The frequency of hypoglycaemia was reduced, as was the need for injectable hypoglycaemia treatment (OR 0.41, 95%CI 0.23-0.77).

There was a reduction in the composite outcome of any complications occurring during admission (OR 0.71, 95% CI 0.58-0.87). For individual complications, there was a statistically significant reduction in pneumonia and foot ulcers.

Conclusions

The DICE project resulted in a significant reduction in drug errors and rates of hypoglycaemia requiring injectable treatment. It was associated with reductions in a composite of all complications during admission, and with significantly lower occurrences of foot ulcer and pneumonia.

BACKGROUND

The 2017 National Diabetes Inpatient Audit (NaDIA), involving 209 hospitals across England and Wales, revealed that 17.9% of inpatient beds were occupied by patients with diabetes (1); this figure has steadily increased from 15% in 2011 (2). The audit also revealed that the quality of care received by this growing proportion of the inpatient population is inadequate.

Patients with diabetes have poorer outcomes than those without diabetes: they have longer length of stay by up to three days, over 7% higher 30-day readmission rates, higher rates of post-operative complications, and higher mortality (3; 4). In addition, inpatients with diabetes report dissatisfaction with the care they receive, particularly in relation to meal timing and quality, and lack of confidence in the staff caring for their condition (5). There are a number of factors that contribute to poor outcomes and patient experience for inpatients with diabetes.

Institutional factors

Treatment for diabetes is individualised and patients are often empowered to manage the condition, with this being tailored to their usual routine. On admission to hospital, patients experience disruption to their routine, most notably with respect to meals and access to their medications; this impacts those with diabetes disproportionately. Often, patients who usually have their main meal in the evening and a bedtime snack find that the main cooked meal is at lunchtime and, in most institutions, a teatime sandwich is all that is provided in the evening. This change in meal patterns and lack of bedtime snack undoubtedly contributes to the higher proportion of overnight hypoglycaemia which has been reported in several studies in inpatients with diabetes, and confirmed in the 2017 National Diabetes Inpatient Audit (6; 7). Rebound hyperglycaemia may follow, and this resulting dysglycaemia is both unpleasant and harmful for patients, and can also be challenging for staff (8).

Non specialists manage diabetes patients

The majority of inpatients with diabetes are admitted for other primary reasons, with diabetes present as a comorbidity. Therefore, they are most commonly under the care of non-specialists or non-diabetologists (7). A number of studies have shown both nursing and medical staff are not confident managing patients with this increasingly common condition and particularly in adjusting their medication. Several trusts have implemented teaching programmes and staff training to address this knowledge gap, however translation of this education into improved glycaemic control and patient outcomes has yet to be demonstrated.

Drug errors are common

The National Inpatient Diabetes Audit in 2016 revealed that 1 in 10 patients with diabetes experiences an episode of hypoglycaemia, with 1 in 50 experiencing hypoglycaemic coma (7). Medication management errors and errors in their prescriptions are frequently the cause of these events, and insulin has been highlighted the third most common cause of avoidable patient harm in hospital by the National Patient Safety Association (NPSA) with reports of significant harm including death (9;10). Despite the introduction of alerts, hypoglycaemic medication errors have been noted in 41% of patients and for 46% for those on insulin (7). Insulin prescription errors are a national concern; overdose of insulin due to use of abbreviations or the incorrect device is listed as a 'never event' by NHS Improvement (11), but still occurs not infrequently in hospitals across England and Wales (7). In addition to affecting patient experience, medication errors by both failure to prescribe, administer or adjust medication appropriately can result in dysglycaemia and impact on patient outcomes.

Hypoglycaemia is associated with increased mortality

A number of studies have demonstrated an association between hypoglycaemia and in-hospital mortality, among both insulin-treated and non-insulin treated patients across a range of clinical groups (12) (13). Whilst a 2-3 fold higher mortality is seen in patients with hypoglycaemia a causal link has not been demonstrated and hypoglycaemia is suspected to be a marker of disease severity (13) (14). Regardless of the cause, hypoglycaemia in hospital is associated with longer length of stay (15) and measures to minimise iatrogenic hypoglycaemia may attenuate this effect.

Hyperglycaemia is associated with more complications

The impact of hyperglycaemia has been well documented in surgery, notably orthopaedic and cardiothoracic surgery (16). Lower limb arthroplasty carries a 3-4 fold increased risk of peri-prosthetic infection in association with perioperative hyperglycaemia (17). Additionally, hyperglycaemia is associated with delayed surgical wound healing with higher wound infection rates by three to seven-fold seen across the surgical specialities (18) (19). In patients with hyperglycaemia and undiagnosed diabetes prior to surgery the post-operative morbidity is higher with increased rates of resuscitation, need for re-intubation, prolonged ventilation and increased mortality (19) (20).

Although associations between poor glycaemic control and complications have been seen in a range of inpatient groups, the impact of glycaemic control and improved inpatient diabetes care on complication rates has yet to be demonstrated (21).

The DICE programme was set up as a multifaceted approach to managing inpatient diabetes care, innovated and implemented by diabetes specialist nurses to address the care challenges which patients with diabetes face. We have previously demonstrated that the DICE programme results in significant reductions in length of stay without any significant increase in readmission, however the impact and possible reasons for this at a patient level were not addressed (22).

AIMS

The aims of this study were to assess the impact of the DICE programme on: 1. patient harms, including insulin and oral hypoglycaemic agent (OHA) errors; and 2. complications, both infective and non-infective (23).

METHODS

Study design

This was a single centre prospective, non-randomised evaluation of standard inpatient care for patients with diabetes before and after a nurse-delivered service development initiative, 'the DICE programme'.

Study setting and study period

The study was carried out in Ipswich Hospital, a 200-bed district general hospital in the UK. The duration of the study was 1st January 2013 to 30th June 2014. Implementation of changes took place between 1st July 2013 and 31st December 2013. Data was therefore collected over two six-month periods before and after the DICE implementation period.

Study participants

All adult patients with type 1 or type 2 diabetes admitted to medical and surgical wards for more than 24 hours or with an overnight stay during the study period were included in the study. Inpatients admitted to the acute medical assessment unit, adult medical inpatient wards, including oncology, and adult surgical inpatient wards were included; inpatients admitted to the obstetrics and gynaecology ward or directly to the intensive care unit were

not included. Patients attending for day case surgery or ambulatory procedures and investigations were not included.

Description of intervention

Prior to implementation of the DICE programme, there was one diabetes specialist nurse working within the hospital trust. Medical and surgical wards were visited by the nurse from Monday to Friday to trouble-shoot, supporting nursing staff in managing patients with diabetes and patients with diabetes directly. Two diabetes specialist nurse posts were funded within the trust in 2013, with an orthopaedic nurse and medical admissions unit nurse appointed to the positions. Their role was to collect data about outcomes of patients receiving diabetes care and to support a seven-day service within the trust. They observed the usual practice in order to innovate changes to improve care. This observation was undertaken whilst undergoing training for the diabetes specialist nurse role. During the baseline data collection period, the nurses observed how the trust and different wards functioned in terms of diabetes care. They met weekly to discuss the challenges and deficiencies in staff knowledge and patient care, and to suggest these might be tackled with service redesign. The diabetes inpatient service was transformed using a whole systems approach from a reactive to a proactive service, employing the innovations detailed below. These were implemented between July and December 2013.

1. *Proactive patient review:* Two electronic systems were set up to enable the nurses to review patients with diabetes in collaboration with the local IT team.
    a. The Abbott glucose monitoring system was electronically linked to patient identifiers, patient ward and location to produce a daily list of hypoglycaemic

events. This allowed nurses to review and suggest adjustments to medication to reduce recurrent hypoglycaemia.

b. The IT department set up a system to generate a daily list of inpatients with diabetes. Patients with diabetes were identified in three ways: previous admission records documenting patients who had previously been seen in the hospital and who had a diagnostic code of diabetes; alerts from the patient electronic health record (flags added to the Evolve patient record); and patients seen in the Diabetes Centre (SystmOne). This method was found to identify patients with diabetes with approximately 98% accuracy.

2. *Diabetes Patients At Risk (DPAR)* is an electronic referral system which risk stratifies patients with diabetes allowing the nurses and foot team to prioritise incoming referrals (24).
3. *A Monthly audit*, like a mini-NaDIA, was incorporated into usual practice. This assessed foot checks, and drug prescription, management and administration errors.
4. *The DICE chart*, a comprehensive drug chart and information tool was implemented. This incorporated drug prescribing, monitoring and guidance for management of hyper- and hypoglycaemia, to improve awareness of doctors and nurses on the wards.
5. Staff education, at regular intervals, for both junior doctors on induction and nursing staff was set up to empower them in managing patients with diabetes using the tools at hand and to advise them when and how to contact the diabetes inpatient specialist nurses.

6. Weekly meetings were held to discuss the service and any problems in implementing these changes, and to identify areas for further development of the service.
7. Nurse-led follow-up phone calls and clinics to facilitate safe and timely discharge of inpatients.

Data collection

Baseline data was collected from January 2013 to June 2013 and follow-up data collected from January 2014 to June 2014. Data was extracted from patient bedside notes; where information was missing, this was supplemented by data from discharge notes in the patient electronic health records. Data was entered into an electronic database by a trained team of nurses. All included wards were visited every 48 hours by the audit nurses, including at weekends, and data was entered into the database for each patient at each visit. Information on the following study outcomes was collected: patient harms, including drug and insulin prescription errors and management errors; and predetermined complications, including myocardial infarction (MI), falls, foot ulcer, acute renal failure, diabetic ketoacidosis/hyperosmolar hyperglycaemic state (HHS), cerebrovascular accident (CVA), urinary tract infection, pneumonia, sepsis and wound infection. These were recorded when documented as a diagnosis by a qualified doctor and appropriately treated for.

The primary nurse making each data entry was recorded. To ensure consistency of data collection between nurses, a random sample of 5% of patient notes were independently audited against the data entries periodically during the data collection period. Where inconsistency was identified, data was edited and standardised by the diabetes specialist nurse responsible for leading the collection of study data. Occasional discrepancies were

noted in timing of admission with no errors in documentation of the frequency of complications for the nurses regularly involved in data collection.

Data was collected in 48-hour periods and was cleaned in an ongoing process to remove duplicate entries, which arose if two specialist nurses recorded information on the same patient during the same 48-hour period. Data for each 48-hour period collected for an individual patient was combined to form a single entry for each patient admission; any duplicate patient records at this stage were removed. The bedside data was pseudonymised and matched with demographic information for each patient with the assistance of the hospital IT department using patient administration system (PAS) data containing age, sex, ethnicity, Index of Multiple Deprivation (IMD) category, modified Charlson comorbidity score, Intensive Therapy Unit (ITU) admission during hospitalisation and Health Resource Group (HRG).

Analysis

A before and after analysis was performed. Outcomes in the 6-month periods before and after implementation of the DICE project were compared. Pre-DICE analysis was performed from 1st January 2013 to 30th June 2013; post-DICE analysis was performed from 1st January 2014 to 30th June 2014.

Baseline patient data comprised merged bedside-collected data and PAS data. Linkage with the administrative (PAS) dataset was 95.2%. Baseline characteristics are presented as mean (standard deviation) or median (interquartile range) for continuous variables, and as proportions for categorical/binary variables.

Primary outcomes were prescription and management errors for insulin and oral hypoglycaemic agents, and frequency of the predetermined in-hospital complications. The secondary outcome was the use of injectable therapy for hypoglycaemia or hyperglycaemia. Medication errors were defined using NaDIA audit criteria (25). The presence or absence of these harms and complications were determined for each patient admission and treated as a binary variable (representing one or more harm or complication during the admission). Logistic regression was used to compare the odds of prescription errors and complications pre- and post-implementation of DICE. Crude and adjusted odds ratios (OR) were calculated; adjusted ORs were adjusted for the following covariates: age, sex, ethnicity, IMD category, modified Charlson comorbidity score, ITU admission during hospitalisation, and HRG.

It was not possible to merge all bedside data with the PAS records. Therefore, a sensitivity analysis was carried out using only the bedside dataset and there was no significant difference in the baseline characteristics between the groups.

All statistical analysis was carried out using STATA 14.2.

RESULTS

Baseline patient characteristics are presented in Table 1. 1905 and 1777 patients were included in the before (2013) and after (2014) groups respectively. Median age on admission was 76 years in both cohorts with 52% in 2013 and 55% in 2014 being males. A large proportion of the population in both cohorts were white Caucasians (>85%). Charlson

comorbidity score, proportion of elective patients (above 80%), and distribution across HRG and IMD categories were similar between the two patient cohorts.

Drug errors

There was a substantial and highly statistically significant reduction in drug errors in the six-month period following implementation of DICE compared to the same period a year earlier. Insulin and oral hypoglycaemic agent prescription errors were reduced by 50%: adjusted OR 0.41 (95% CI 0.32-0.5) and 0.50 (95% CI 0.41-0.62) for insulin and OHAs respectively. Management errors were reduced by approximately 80%: adjusted OR 0.17 (95% CI 0.12-0.24) and 0.18 (95% CI 0.13-0.27) for insulin and OHAs respectively. There was a statistically significant reduction in the need for injectable hypoglycaemia treatment, adjusted OR 0.41 (95% CI 0.23-0.77), but there was no difference in the need for injectable treatment for hyperglycaemia: adjusted OR 1.07 (95% CI 0.84-1.38, p = 0.58) (Table 2, Figure 1).

Complications

Following implementation of DICE, there was a significant reduction in the number of patients with one or more complications during their hospital stay: adjusted OR 0.71 (95% CI 0.58- 0.87) (Table 3, Figure 2).

The frequency of all infective complications – pneumonia, urinary tract infection (UTI), sepsis and wound infection – was reduced following implementation of DICE, however, the difference was statistically significant only for pneumonia: adjusted OR 0.51(95% CI (0.13-0.27).

Among non-infective complications, there was a substantial and statistically significant reduction in occurrence of foot ulcers: adjusted OR 0.15 (95% CI 0.03-0.69). The frequency of acute kidney injury and acute MI was reduced, but the results were not statistically significant. The number of patients with stroke, cardiac arrest, and diabetic ketoacidosis (DKA)/ hyperosmolar hyperglycaemic state (HHS) outcomes was very small; ORs were therefore not calculated. There was a non-statistically significant increase in the number of falls post-implementation of DICE: adjusted OR 1.19 (95% CI 0.78-1.81; p = 0.40).

Table 1. Baseline patient characteristics	2013	2014
Total patients	1905	1777
Sex, n (%) male	990 (52.0)	986 (55.5)
Age, median (IQR)	76 (65, 83)	76 (66, 84)
Modified Charlson comorbidity score, n (%)		
0	858 (45.0)	786 (44.2)
1	373 (19.6)	331 (18.6)
2 or more	674 (35.4)	660 (37.1)
Elective, n (%)	1592 (83.6)	1515 (85.3)
HRG, n (%)		
A (Nervous system, pain management)	114 (6.0)	114 (6.4)
B (Eyes and periorbital)	3 (0.2)	5 (0.3)
C (Mouth, head, neck, ears)	47 (2.5)	39 (2.2)
D (Thoracic)	275 (14.4)	224 (12.6)
E (Cardiac)	301 (15.8)	261 (14.7)
F (Digestive system)	245 (12.9)	218 (12.3)
G (Hepatobiliary and pancreatic system)	56 (2.9)	72 (4.1)
H (Orthopaedic)	209 (11.0)	208 (11.7)
J (Skin)	41 (2.2)	59 (3.3)
K (Endocrine system)	124 (6.5)	116 (6.5)
L (Renal, urological, male reproductive system)	211 (11.1)	179 (10.1)
M (Female reproductive system)	22 (1.2)	21 (1.2)
N (Obstetric)	1 (0.1)	6 (0.3)
P (Paediatric)	10 (0.5)	41 (2.3)
Q (Vascular)	71 (3.7)	10 (0.6)
R (Diagnostic imaging)	13 (0.7)	22 (1.2)
S (Haematological, chemotherapy, radiotherapy, specialist palliative care)	25 (1.3)	25 (1.4)
V (Trauma, emergency medicine, rehabilitation)	9 (0.5)	157 (8.8)
W (Immunology, infectious diseases, other healthcare contacts)	128 (6.7)	0 (0.0)
IMD*		
0 (most deprived)	468 (24.8)	467 (26.4)
1	404 (21.4)	366 (20.7)
2	343 (18.1)	341 (19.3)
3	326 (17.2)	299 (16.9)
4 (least deprived)	349 (18.5)	296 (16.7)
Ethnic Group		
White	1696 (89.0)	1521 (85.6)
BlacK African and Caribbean	15 (0.8)	22 (1.2)
Asian	29 (1.5)	22 (1.2)
Not categorised	165 (8.7)	212 (11.9)

* IMD was missing for 15 patients in 2013 and 8 patients in 2014.

Table 2. Drug prescription errors

Prescription error	2013, n (%)	2014, n (%)	Crude OR	Adjusted OR (95% CI)	p-value
Insulin prescription error	314 (16.48)	133 (7.48)	0.41	0.41 (0.32-0.50)	<0.001
Insulin management error	232 (12.8)	43 (2.42)	0.18	0.17 (0.12-0.24)	<0.001
Injectable hypoglycaemia treatment	38 (1.99)	15 (0.84)	0.42	0.41 (0.23-0.77)	0.005
Injectable hyperglycaemia treatment	141 (7.40)	146 (8.22)	1.12	1.07 (0.84-1.38)	0.578
OHA prescription error	266 (13.96)	136 (7.65)	0.51	0.50 (0.41-0.62)	<0.001
OHA management error	188 (9.87)	37 (2.08)	0.19	0.18 (0.13-0.27)	<0.001

Table 3. Patient in-hospital complications

Complication	2013, n (%)	2014, n (%)	Crude OR	Adjusted OR (95% CI)	p-value
One or more complication	258 (13.54)	182 (10.24)	0.73	0.71 (0.58- 0.87)	0.001
Acute kidney injury	61 (3.2)	40 (2.25)	0.70	0.70 (0.46-1.06)	0.095
Acute MI	12 (0.63)	5 (0.28)	0.45	0.54 (0.18-1.62)	0.27
Foot ulcer	13 (0.68)	2 (0.11)	0.16	0.15 (0.03-0.69)	0.015
DKA/HHS	1 (0.05)	1 (0.06)	-	-	-
Pneumonia	52 (2.73)	25 (1.41)	0.51	0.51 (0.13-0.27)	0.007
UTI	37 (1.94)	32 (1.8)	0.93	0.88 (0.53-1.43)	0.61
Sepsis	83 (4.36)	61 (3.43)	0.78	0.79 (0.55-1.12)	0.19
Wound infection	7 (0.37)	5 (0.28)	0.77	0.76 (0.23-2.57)	0.66
Cardiac arrest	1 (0.05)	3 (0.17)	-	-	-
Fall	43 (2.26)	53 (2.98)	1.33	1.19 (0.78-1.81)	0.398
Stroke	2 (0.1)	1 (0.06)	-	-	-

MI: myocardial infarction; DKA: diabetic ketoacidosis; HHS: hyperosmolar hyperglycaemic state; UTI: urinary tract infection.

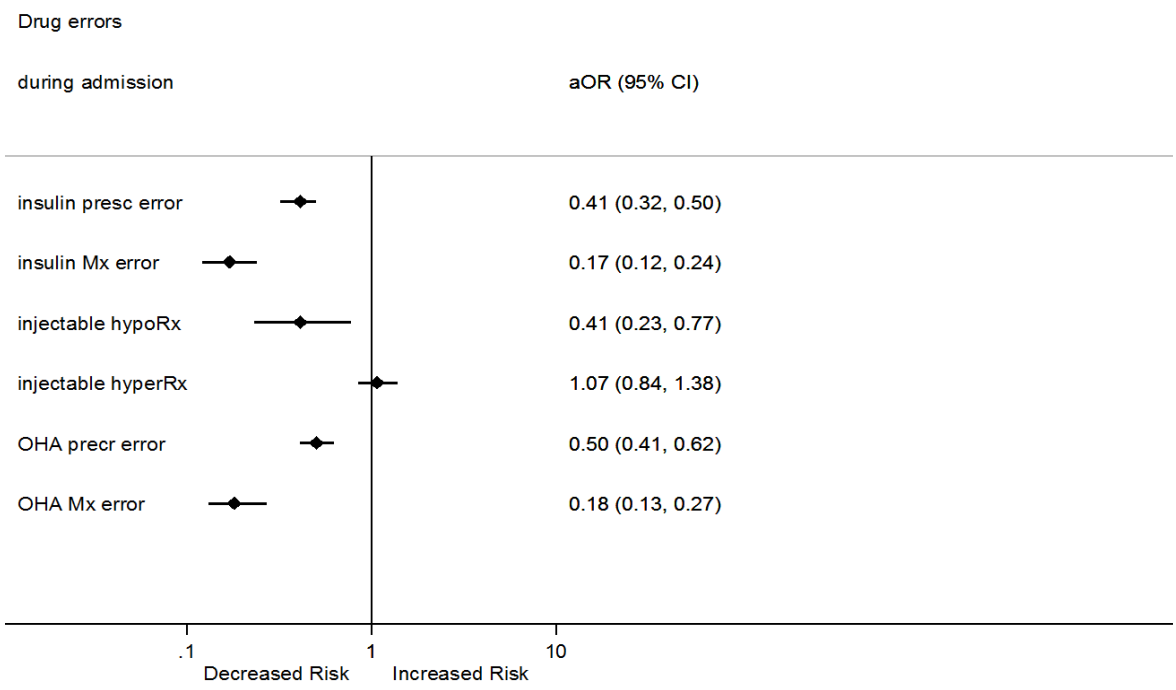

Figure 1. Forest plot showing odds ratios (with 95% CI) for drug prescription errors.

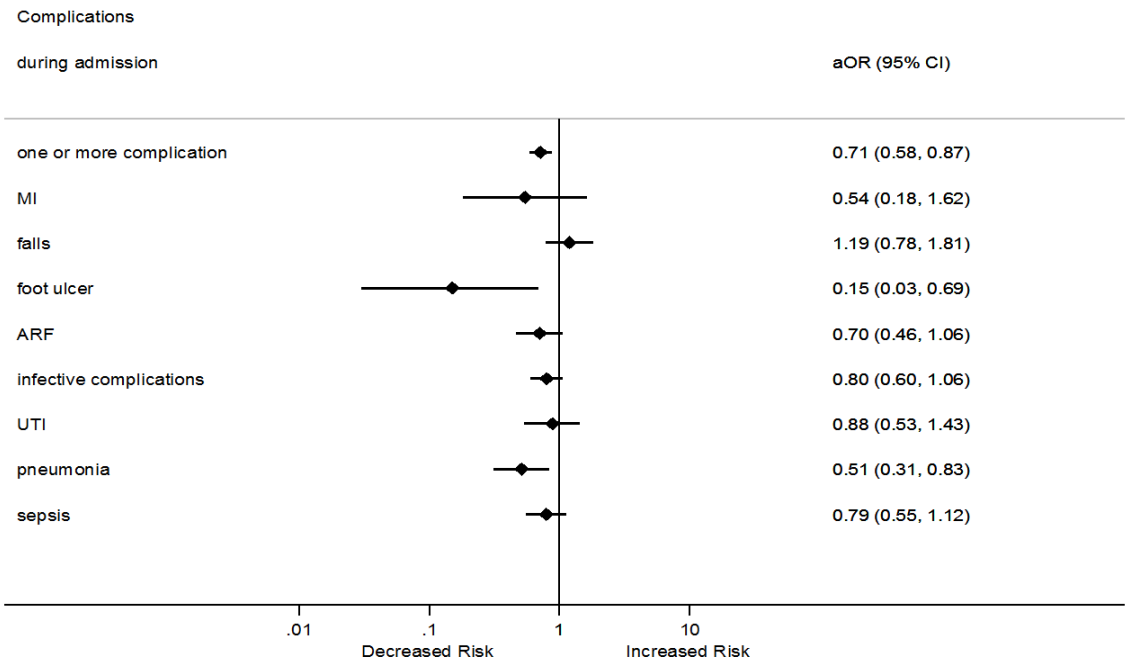

Figure 2. Forest plot showing odds ratios (with 95% CI) for complications.

DISCUSSION

Drug errors

Following the implementation of DICE, a multifaceted programme for improving diabetes inpatient care delivered by a dedicated inpatient diabetes specialist nurse team, there was a 59% reduction in the occurrence of insulin prescription errors and an 83% reduction in insulin management errors. There were also reductions of 49% and 82% in errors made in the prescribing and managing oral hypoglycaemic agents following implementation of DICE. These findings are in keeping with a study by Courtenay and Carey, where establishment of a diabetes specialist nurse prescriber was associated with a 52% reduction in the frequency of all drug errors (26).

The most notable reductions in our study were in management errors for insulin and oral hypoglycaemic agents, with reductions of 83% and 82% respectively. This is perhaps due to the education of staff and the development of a clear protocol for management of both hypo- and hyperglycaemia, allowing ward staff to make or suggest treatment adjustments outside of the working hours of the specialist nursing team. In addition, the use of injectable hypoglycaemia treatment reduced significantly, indicating successful management of hypoglycaemia and a reduction in recurrent hypoglycaemia, as we have reported previously (27). Anon-significant rise in injectable therapy to treat hyperglycaemia was observed suggesting that nurses were more proactive in managing patients with elevated glucose levels. There have been no studies analysing the impact of a diabetes specialist nurse led service on glycaemic control and this is an area for further research.

Complications

This is the first study to demonstrate a significant reduction in complications in unselected patients with diabetes upon implementation of a nurse-delivered whole systems approach to diabetes inpatient management. Most notably there were significant reductions in the proportions of patients developing foot ulcers or pneumonia during their hospital admission, with reductions of 86% and 49%, respectively, following implementation of the DICE programme. Non-significant reductions were seen in other infective complications (sepsis, UTI and wound infection) as well as non-infective complications (MI and AKI).

A systematic review looking at the introduction of specialist nurses across a range of specialities has previously shown that their presence leads to reductions in pressure ulcers, however this paper included only one study with diabetes specialist nurses (28). The diabetes specialist nurses in our study were not involved in foot care directly, however this was promoted and audited by them and prompted as a daily check on the DICE chart. It may therefore be that the visibility and accessibility of the nurses, as well as a clearly defined pathway and mechanism for raising concerns (DPAR), resulted in this reduction.

Evidence that the proactive insulin adjustment approach and bedtime snack components of the DICE programme reduced recurrent hypoglycaemia has been presented previously (27). We postulate that improved glycaemic control with reductions in glucose variability and the need for intravenous hypo- and hyperglycaemia treatment resulted in fewer patients acquiring in-hospital complications, particularly infections. This is supported by the studies

by Umpierrez which showed that basal bolus control significantly reduced the occurrence of composite complications when compared to correctional insulin boluses in hospitalised general surgical and non-surgical patients with type 2 diabetes (29; 21). This striking reduction in hospital acquired complications is likely to be a key factor in the reduced length of stay we previously demonstrated in association with the DICE programme (22) . Improved overall care therefore carries a potentially large cost saving benefit through improved glycaemic control for hospitalised patients.

Study strengths and limitations

A pragmatic before and after study design was used with no control patient group. This study design does not account for temporal trends in the outcomes measured, or for the effects of unknown confounders, such as other changes in healthcare provision occurring during the intervention period. Any underlying secular trends may therefore impact on the observed effect sizes.

The study included patients from medicine, oncology and surgery and is therefore generalizable to the majority of patients in a district general hospital context. This was a real-world study investigating the implementation of a specialist nurse-delivered hospital programme for inpatients with diabetes. As such, these practical and sustainable changes may be implemented in other trusts by a diabetes specialist nursing team.

The labour-intensive method of data collection makes it difficult to carry out a repeat study to verify the data given current hospital documentation and staffing-levels. Despite the arduous data collection process, a six-month period was sampled before and after the implementation of DICE enabling the documentation of a number of significant changes. It is likely that some of the infective complications would show a statistically significant change with a longer period of data collection, however this was impractical. The same six-month periods (January to June) were used in the before and after datasets (2013 and 2014) in order to limit any effect of seasonal changes on the patient cohort.

CONCLUSION

This study demonstrates the potential clinical benefits of innovating and implementing a whole systems approach to diabetes care, with improvements in patient harms and in-hospital complications. This is the first study to show reductions in complications through implementation of a multifaceted specialist nurse led diabetes service. The setting was medical and surgical wards, making the intervention broadly applicable to other district general hospitals. However, the before and after study design limits the applicability of these promising results. A randomised controlled trial should be carried out in order to build on this evidence and confirm the findings.

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CHAPTER 5

Chapter 5: Management of Hyperglycemia and Diabetes in Orthopedic Surgery

This chapter provides an overview of the management of hyperglycaemia and diabetes in one of the best evidenced areas in terms of outcomes, orthopaedic surgery. With this concept proposed I determined the contents and design of this narrative review. A number of layouts were considered, including presenting the information by joint or limb for both diabetes and hyperglycaemia, however this division was not possible due to research gaps. The available data is compiled as a chronological journey through the perioperative pathway.

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Management of Hyperglycemia and Diabetes in Orthopedic Surgery

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Abstract An increasing number of orthopedic operations are being carried out in an older population in whom the prevalence of diabetes is dramatically increasing. People having surgery with diabetes and hyperglycemia are at increased risk of post-operative complications. The peri-operative risks have been well demonstrated for cardiac surgery and, more recently, for orthopedic surgery. This paper considers the issues surrounding orthopaedic surgery in patients with diabetes and the significance and management of hyperglycemia in the peri-operative period.

Keywords Diabetes mellitus · Hyperglycemia · Peri-operative glucose · Orthopedic surgery · Arthroplasty

Introduction

The global prevalence and incidence of diabetes is steadily rising in all populations and at the current rate the International Diabetes Foundation (IDF) estimates a prevalence of 9.9% worldwide by 2030. With population growth, this represents a 50.7% increase in people affected over a 19-year period [1]. A person with diabetes is more likely to require surgery than a person without and this is particularly notable for orthopedic surgery, which has seen an overall increase in procedures in this population as a whole [2].

Observational studies show that in the surgical patient, diabetes is associated with a higher rate of peri-operative complications such as need for transfusion, pneumonia, delayed discharge, surgical site infections, and in-hospital mortality [3]. These poorer outcomes are in part due to higher rates of co-morbid conditions such as ischemic heart disease, renal impairment, and hypertension in patients with diabetes [4]. Dysglycemia, which encompasses hyperglycemia, hypoglycemia, stress-induced hyperglycemia, and excessive glucose variability, is increasingly observed and associated with poorer post-operative outcomes even in those without a prior diagnosis of diabetes. In fact, several studies have shown post-operative complications occur more frequently in people with stress-induced hyperglycemia with no prior diagnosis of diabetes than in those with diabetes [5–7].

Effect of Surgery on Glucose Levels

Surgery and anesthesia elicit a stress response that produces marked neurophysiological changes with release of adrenaline, noradrenaline, cortisol, glucagon, and growth hormone. This increase in counter-regulatory hormones and cytokines raises glucose levels and increases insulin resistance. In susceptible patients, this may result in significant hyperglycemia [8]. Additionally, elements of the surgical process such as disturbed eating patterns due to fasting or post-operative nausea, omission of insulin or hypoglycemic medication, and complications such as wound infection can all contribute to dysregulation of glucose homeostasis in the peri-operative period. The resulting raised, low, or erratic glucose levels have all been associated with poor outcomes.

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Effect of Glycemia on Outcomes for Orthopedic Surgery

Hyperglycemia impairs leucocyte function causing immunocompromise with consequences for superficial and deep tissue infection as well as overall mortality [9].

The detrimental effects of suboptimal glycemic control on surgical outcomes and post-operative complications have been demonstrated across surgical specialities. Within orthopedics, the subspecialties of spinal surgery, arthroplasty, and trauma surgery have been most extensively studied.

Surgical Site Infection

Surgical site infection is the most common hospital acquired infection and is associated with worse functional outcomes and increased amputation rates in patients undergoing orthopedic surgery [10, 11]. Rates of surgical site infection are significantly increased in patients with diabetes, most notably in those with suboptimal glycemic control. Preoperative HbA1c levels above 7.0% have been found to be associated with higher rates of surgical site infection for thoracic and lumbar spinal instrumentation surgery (35.3% compared with 0.0%) [12]. The incidence of surgical site infections has also been linked to peri-operative hyperglycemia in people without a prior diagnosis of diabetes. In this group, stress-induced hyperglycemia >200 mg/dL (11.1 mmol/l) is an independent risk factor for surgical site infection at 30 days (OR 3.2, 95% CI: 1.3–7.8) even after adjustment for open fractures [13]. Following trauma, a 7-fold increase in peri-operative infections has been seen with peri-operative hyperglycemia >220 mg/dL (12.2 mmol/l, $P = 0.0056$) [6].

Peri-prosthetic Infection

Although uncommon, occurring in around 1% of arthroplasties, peri-prosthetic infection is one of the most devastating orthopedic complications for patients and surgeons and may require further surgery to treat effectively [14]. No significant association has been demonstrated between peri-operative HbA1c and peri-prosthetic infection at the hip or knee; however, both pre- and post-operative hyperglycemia have been associated with this serious complication [15•, 16]. Morning post-operative hyperglycemia >140 mg/dL(7.8 mmol/L) is associated with a 3-fold increased risk of peri-prosthetic infection (27/285 compared with 20/582) [17]. In a series of 1565 primary knee arthroplasties, Jämson and colleagues showed a 4-fold increase in people with a peri-operative glucose >6.9 mmol/L compared with those with a normal reading of <6.1 mmol/L [18].

Other Complications, Length of Stay, and Morbidity

It is apparent that glycemia correlates with multiple poor post-operative outcomes in orthopedic surgery, including mortality. Raised HbA1c is associated with increased length of hospital stay and is a predictor of risk for pulmonary embolism following orthopedic surgery [19]. Pre-operative HbA1c over 6.5% has been shown to be a significant risk factor for surgical outcome with a poor post-operative recovery rate following cervical laminoplasty (OR 2.6, $P = 0.02$) [20]. Undergoing primary joint arthroplasty with an HbA1c above 7.0% carries an increased mortality (HR 1.3, $P = 0.01$) [15•].

Glycemic Management and Surgical Outcomes

Despite the above associations, the key question is whether treating hyperglycemia reduces complications and improves these outcomes. There are no randomised studies in orthopedic surgery; however, one observational study by Agos et al. demonstrated that implementation of an evidence-based standard to control hyperglycemia reduced the rate of surgical site infection in people undergoing hip and knee replacement surgery [21••].

Treating hyperglycemia in the peri-operative period has been shown to reduce complications in other surgical disciplines. Trussel and colleagues demonstrated reductions in surgical site infection with tight peri-operative glycemic control in people having coronary artery bypass grafting (CABG) surgery [22]. Similarly, Furnary and colleagues showed reductions in mortality and deep infection rates by treating people with diabetes undergoing cardiac surgery; the lowest rates seen in people targeted under 150mg/dL (8.3 mmol/L) [23]. In general surgery, Umpierrez showed that lower rates of hyperglycemia, using a basal bolus regime, was associated with reduced incidence of wound infection, pneumonia, bacteremia, and respiratory and acute renal failure [24]. These limited data have provided the basis for the American Association of Clinical Endocrinologists (AACE) and American Diabetes Association (ADA) guidelines, the Joint British Diabetes Society (JBDS) guidelines, and others all advocating treatment of hyperglycemia for hospitalized patients peri-operatively [25–27]. The target glucose ranges for these guidelines are summarized in Table 1.

The Effect of Diabetes and Its Complications on Peri-operative Risk in Orthopedics

Diabetes irrespective of glycemia is associated with greater surgical risk because of the higher incidence of co-morbid conditions, including obesity, sleep apnea, hypertension, in addition to the micro- and macrovascular complications that are associated with the condition. In people with diabetes,

Table 1 Peri operative glucose targets in national guidelines

Group	Target (noncritically ill patients)	Publication year
Joint British Diabetes Societies	6 10 mmol/L (108 180 mg/dL) target	2012
For NHS Diabetes (26)	4 12 mmol/L (72 216 mg/dL) acceptable	
AACE/ADA/Endocrine society (25)	<140 mg/dL (7.8 mmol/L) and a random BG of less than 180 mg/dL (10.0 mmol/L)	2009
	Consider lower targets in those with previously tight control	
Canadian Diabetes Association (27)	Fasting 5.0 8.0 mmol/L (90 144 mg/dL)	2013
	Random <10 mmol/L (if safely achievable)	
The Association of Anaesthetists of Great Britain and Ireland (56)	6 10 mmol/L (108 180 mg/dL) target (intra operatively)	2015
	6 12 mmol/L (108 216 mg/dL) acceptable	

surgery at the hip, knee, ankle, and elbow is associated with higher rates of post-operative infection, need for transfusion, pneumonia, urinary tract infection, length of stay, non-routine discharge, and in-hospital mortality [28, 29].

The condition of diabetes, in a recent meta-analysis, has shown an increased surgical site infection rate from pooled US data with OR 1.26 (95% CI 1.01–1.66) for arthroplasty and 1.6 (CI 1.10–2.32) for spinal surgery after accounting for impact of hyperglycemia and adjusting for BMI [30]. Interestingly, diabetes treated with insulin has been linked to increased 30-day readmission rates for people undergoing arthroplasty [31]. This may relate to disease chronicity, which has been associated with poor outcomes in cervical laminoplasty for people with 10 or more years duration of diabetes [20].

Neuropathy and vascular insufficiency, which may complicate diabetes, presents challenges for lower limb and particularly foot and ankle surgery, for which a modified approach is taken. Subsequent hospital-acquired foot ulceration in high risk feet can take several months to heal and superadded infection may complicate these ulcers, increasing the risk of peri-prosthetic infection and amputation [32].

Diabetic Cardiovascular Disease and Surgery

A 2- to 3-fold increased prevalence of cardiovascular disease in people with diabetes makes surgery a higher-risk undertaking for this group [33, 34]. Hyperglycemia causes an osmotic diuresis, and the resulting hypovolemia and electrolyte disturbance may be further exacerbated by nausea and vomiting caused by anesthetic agents. The result may be tachycardia, hypokalemia, and hypomagnesemia with the resulting arrhythmias contributing to the increased peri-operative cardiovascular mortality in these patients [35].

As cardiac ischemia may be 'silent' in people with diabetes, a baseline ECG should be carried out in all people with diabetes prior to surgery. The threshold for cardiology referral and further investigations should be determined locally but based on the relevant national guidelines.

The following sections deal with peri-operative clinical assessment of elective surgery from pre-hospitalization through to discharge including pre-operative assessment, hospital admission, theater and recovery, and the post-operative period. The considerations of pumps, steroid-induced hyperglycemia, and emergency surgery are also discussed.

Prehospitalization Assessment

Surgical Outpatients

It is clear from the previous discussion that the orthopedic surgeon's decision to proceed to surgery should include some assessment of the surgical risk to the patient with diabetes taking into account their diabetic complications and other comorbidities. High risk patients should be highlighted prompting early review, usually in a pre-assessment clinic to assess and optimize medication, glycemia, and blood pressure control prior to surgery. Specialist referrals for detailed assessment and optimization of diabetes or its cardiac or renal complications can be initiated at this stage.

One of the aims throughout the peri-operative process is to reduce the glycemic variability that may result from meal disruption and surgery itself.

Glycemic variability can be described as the degree to which glucose values fluctuate between peaks and troughs for an individual. There is no universally agreed ideal method to calculate it at present. It has emerged as a contributing factor for macro- and microvascular complications in the outpatient setting in people with both type 1 and type 2 diabetes. However, its impact in hospitalized patients has yet to be fully established. There are studies highlighting its importance in the critical care and peri-operative setting. A retrospective study by Egi et al. looked at 7049 critically ill patients with glucose measurements taken at least 4-hourly. Glucose variability was an independent risk factor in predicting mortality in ICU and hospitalized patients with

an OR of 1.28 per mmol/LSD for variability and 1.21 per mmol/L for glucose level, hinting that glycemic variability is at least as important as hyperglycemia this patient group [36]. Although there are no prospective randomized trials demonstrating the impact of glycemic variability on orthopedic complications or that reducing variability improves outcomes, it is sensible to aim to limit glycemic variability until evidence to the contrary emerges.

In order to minimize glycemic variability, it is advised that patients with diabetes are prioritized on morning or afternoon lists, thereby limiting the period of fasting and disruption to normal meal times. JBDS guidelines suggest 95% of patients with diabetes should be on the first third of elective lists with avoidance of elective evening surgery altogether [26]. The regimen used to manage inpatient hyperglycemia also impacts on glucose variability, which is discussed later in this article.

Accessible electronic systems can facilitate priorities in care pathways by highlighting those people with diabetes. A flag initiated from first contact and visible throughout the peri-operative journey can be used to prompt actions such as priority list position. The glycemic and non-glycemic considerations throughout the peri-operative period are highlighted in Fig. 1.

Preoperative Assessment

Screening for Diabetes

Since a suspected 1% of the UK population and up to 3% of people in the US are thought to have undiagnosed diabetes, it is increasingly common for diabetes to be detected on pre-operative bloods on the day of surgery. However, screening for diabetes in the pre-assessment period is not routine, but should be considered. One prospective study of people undergoing elective noncardiac surgery found hyperglycemia in over 25% (118/493) of those without a prior diagnosis of diabetes on the morning of surgery [37].

Failure to identify and manage diabetes and hyperglycemia pre-operatively has been shown to increase the risk of complications with higher requirement for resuscitation, re-intubation, longer post-operative ventilation, and increased mortality [7, 38]. Indeed, studies to date suggest that the risk in those not known to have diabetes and those with stress or pre-operative glycemia is several fold greater than those with diabetes.

Guidelines at present do not recommend diabetes screening of patients being assessed for all types of elective surgery. The National Institute of Clinical Excellence (NICE) suggests testing for diabetes in people admitted to hospital at risk of the disease; however, this is generally limited to emergency admissions [39]. The ADA recommends screening for people over the age of 45 years and earlier in those with BMI > 25 kg/m^2 with age adjustment for higher risk ethnic groups [40]. However, for elective orthopedic surgery, one meta-analysis suggests that it should be considered to minimize complications in the peri-operative period [41••]. HbA1c is increasingly being measured for this purpose with a value of 48 mmol/L(6.5%) or more diagnosing the condition in a symptomatic patient [42]. As the prevalence of diabetes rises, there is a potentially huge economic burden, which may result from adopting screening for diabetes in surgical pathways. If screening were adopted for all surgical pathways, this expense would need to be justified with randomized controlled trials. Although the amalgamated research in all non-cardiac surgery may be insufficient to recommend screening in national guidelines, it should be adopted in orthopedic surgery and vascular surgery based on current evidence [41••].

Glycemic Assessment of the Diabetic Patient

Measurement of HbA1c highlights those with poorly controlled diabetes allowing optimization of glycemic control prior to surgery. It may be necessary to delay elective surgery to facilitate this.

There is no evidence-based guideline published that precludes surgery above a particular value for HbA1c; however, most guidelines advise below 8–9% (68–75 mmol/mol) for elective orthopedic surgery as a safe target [26]. In view of the complications correlated with raised HbA1c in orthopedics, some institutions may opt for lower pre-operative values than guidelines recommend. However, data suggests a significant proportion of patients scheduled for arthroplasty will take over 6 months to attain the guideline target HbA1c and for others it may not be feasible [20, 43].

Complications and Comorbidities

The complications of diabetes should be actively assessed and optimized in view of the associated peri-operative risk they contribute. For patients undergoing foot and ankle surgery, it is essential to undertake a preoperative neurovascular assessment of the feet in addition. Neuropathy is associated with increased surgical site infection rates even in those without diabetes. High risk feet can be identified without any equipment using a quick and simple bedside tool, the ‘Ipswich touch test’, prompting pressure relief as soon as convalescent [44]. Pre-operative revascularization may be necessary in some people with significant peripheral vascular disease.

The pre-operative workup for people with diabetes undergoing surgery is covered in detail in both the Joint British Diabetes Societies and ADA guidelines and the additional management considerations relating to diabetes should be incorporated into local orthopedic pathways and proformas to prevent omission of these elements during the peri-operative period. Clear written instructions on the alterations to medications according to local guidelines should be given to patients at pre-assessment.

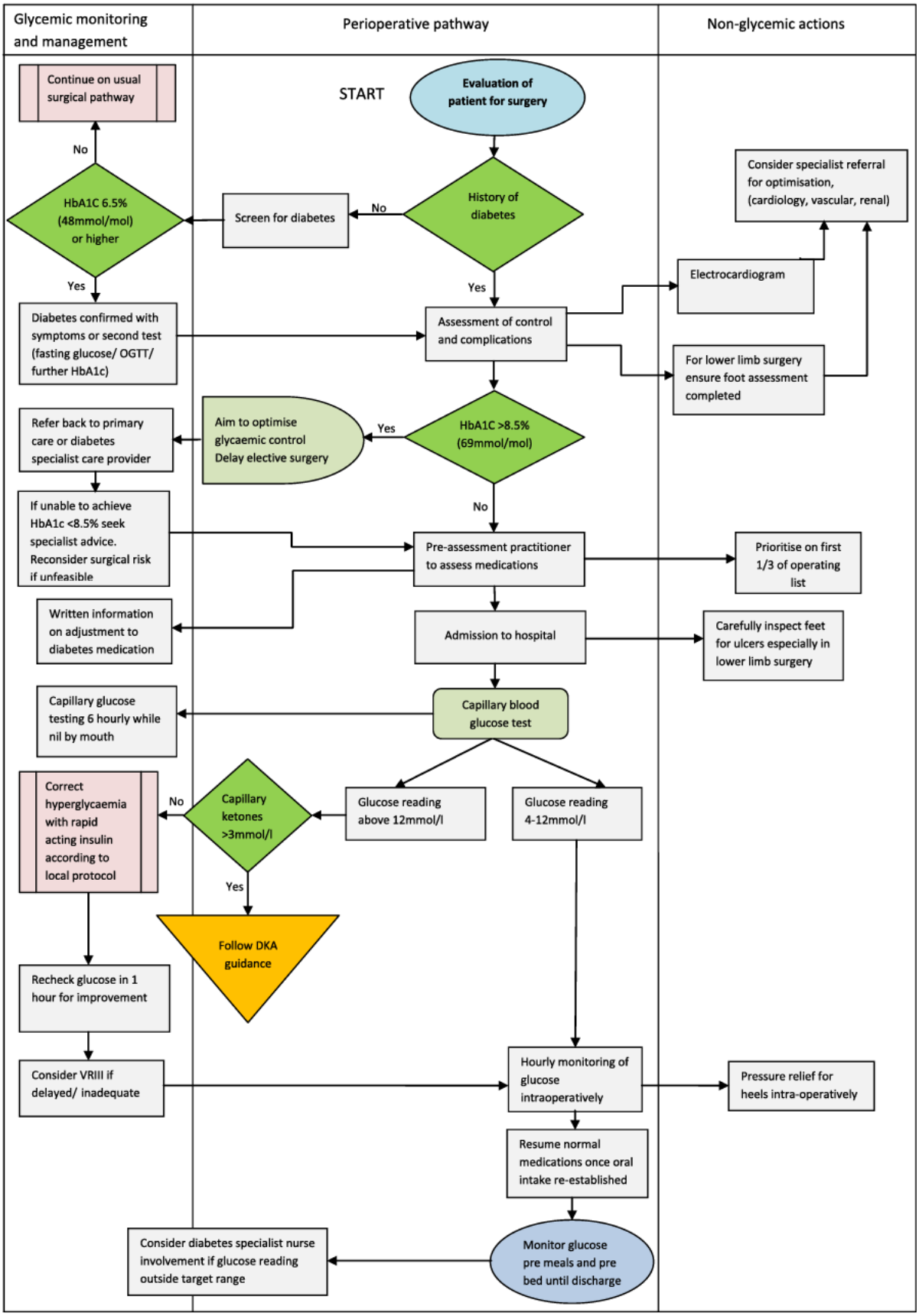

Fig. 1 Orthopedic peri operative pathway decision tool

A self-reporting checklist for patients with diabetes to complete can alert staff to potential problems for further attention.

Hospital Admission

Glycemic Control and Monitoring

The aims of peri-operative glycemic control are avoiding hypoglycemia, marked hyperglycemia, electrolyte disturbance, and the diabetic emergencies of hyperosmolar hyperglycemic state (HHS) and diabetic ketoacidosis (DKA). The target range that is most effective in achieving these aims remains a matter of debate.

The NICE-SUGAR trial and a series of studies challenged the dogma for tight glycemic control outside of the critical care or cardiology setting with increased mortality attributed to higher rates of hypoglycemia [45]. The emphasis is increasingly on adapting the glycemic target to the individual patient and their circumstances. Published guidelines focus on safe rather than tight control with JBDS promoting glucose targets between 6 and 10 with 4–12 mmol/L as an acceptable range. A selection of differing peri-operative targets by country are displayed in Table 1.

Close monitoring in the peri-operative period is required to detect and manage glucose excursions and is advised before meals or 4–6 hourly in patients who are not eating. Blood tests on admission should include a laboratory glucose or capillary blood glucose with point of care testing. There should be clear local policies to optimize glycemic control in the hospital throughout the peri-operative period with methods governed by the individual patient circumstances, the policy and resources of the institution, and clinician's judgement.

Fasting and Enhanced Recovery

Prolonged fasting results in increased insulin resistance in both those with and without diabetes. Higher insulin resistance is associated with poor wound healing, higher complication rates, and increased length of hospital stay. The degree of insulin resistance is greater in larger or more complex operations and those with greater blood loss and through metabolic pathways, it contributes to hyperglycemia [46]. A meta-analysis has shown insulin resistance may be attenuated by half with administration of oral or IV glucose, associated with reductions in length of stay [47]. Pre-operative oral carbohydrate treatment has been widely adopted as part of an enhanced recovery program; a multimodal approach to peri-operative care, which includes early mobilization, minimization of the fasting period, and optimizing pain relief. Enhanced recovery programmes have been shown to reduce length of stay and post-operative complications, most notably in colorectal surgery [48].

Although enhanced recovery programmes show improved post-operative outcomes, there is limited evidence demonstrating the benefits of pre-operative carbohydrate loading specifically within these programmes. The impact of carbohydrate loading in improving a range of post-operative outcomes has been examined in a Cochrane review of 27 randomized controlled trials, including 4 orthopedic studies. The authors of this review concluded that preoperative carbohydrate loading offers small reductions in length of stay; however, complications and well-being are not significantly impacted [49].

There is a paucity of data on the potential impact of pre-operative carbohydrate loading on those with diabetes. A small case controlled study by Gustaffson et al. found no delay in gastric emptying following a carbohydrate drink for subjects with type 2 diabetes compared with healthy volunteers. In this study, peak glucose concentrations occurred later and were higher (13.4 ± 0.5 compared with 7.6 ± 0.5 mmol/l; $P \leq 0.01$) [50].

With the aforementioned concerns about increased complication rates related to peri-operative hyperglycemia, the administration of carbohydrate drinks in people with diabetes requires further study before it is implemented for this group, particularly in orthopedic surgery. The exclusion of people with insulin treated diabetes from these programmes [51] may limit further detailed study of this group.

Immobility and Pressure Ulcers

Pressure ulcers are a problem in surgery, causing pain, reduced quality of life, and prolonged hospital admission; diabetes can increase the risk of pressure ulcers 3-fold. Pressure ulcers following hip surgery can have devastating consequences with associated complication rates ranging from 16 to 46% and an increased mortality rate of 27% [52].

Prevention is the most effective way to approach this problem with simple inspection found to be more effective than currently advocated scoring systems. As the majority of these ulcers develop in-hospital, often on the day of surgery, it is vital that preventative measures commence on admission [53].

The period of immobility should be minimized and feet should be carefully inspected preoperatively for ulceration, which may act as a port for infection that people with diabetes may not self-report due to neuropathy. Multidisciplinary team involvement is crucial in those who develop ulceration as resultant hyperglycemia in those with infected ulcers can create a vicious cycle by delaying wound healing.

Theater and Recovery

Glucose Targets and Glucose Management

There are limited data examining the effect of intra-operative glycemic control on post-operative outcomes with available

studies carried out in cardiac surgery. Doenst et al. showed an intra-operative peak glucose reading >20 mmol/L(360 mg/dL) to be an independent risk factor for poor post-operative outcome and mortality in people with diabetes (OR, 1.20; CI, 1.08–1.32) and without diabetes (OR, 1.12; CI, 1.06–1.19; per mmol/L increase in glucose) [54]. Ouattara et al. found poor intra-operative glycemic control, defined as 4 or more consecutive blood glucose values over 11.1 mmol/L(200 mg/dL), to confer a higher risk of cardiac and noncardiac post-operative complications [55]. The Association of Anesthetists of Great Britain and Ireland (AAGBI) advise an intra-operative glucose target of 6–10 mmol/L with a peak up to 12 mmol/L for less well controlled patients. Ketone testing is advised with intra-operative glucose readings over 12 mmol/L[56].

Glucose testing remains central to maintaining glycemic control and should be carried out prior to induction of anesthesia, then hourly for operations of over 2 hours. For prolonged fasting with more than 1 missed meal or operations over 3 hours, an insulin infusion may be required. In these instances, a glucose, insulin, potassium (GIK) regime may be used, where the 3 elements are combined in a single bag for infusion. However, many institutions favor the variable rate intravenous insulin infusion (VRIII), where insulin and glucose with or without potassium are delivered as separate infusions with titration of the insulin every 1–2 hours. This requires close monitoring and regular adjustment as potentially dangerous glucose excursions can occur when the infusions are mismatched. In a small study looking at patients undergoing cardiothoracic surgery, the VRIII was found to offer more stable glycemic control than the GIK regime [57]; however, there is little evidence in support of one method over the other, and local policy should be followed. VRIII should commence at least 2 hours prior to surgery to allow time for abnormal glucose readings to stabilize.

For people on a long-acting basal insulin, local policies usually advise continuation of the basal insulin with the variable rate insulin infusion. This facilitates transition back to the usual regime when oral intake is reinstated. If the basal insulin is discontinued preoperatively, it must be given 30 to 60 minutes prior to any intravenous insulin being taken down because of the short half-life of intravenous insulin in order to reduce the risk of diabetic ketoacidosis.

Pumps

For people on continuous subcutaneous insulin infusion (insulin pumps) undergoing day case surgery, there is evidence that this may be safely continued intra-operatively for up to 3 hours whilst maintaining safe glycemic control post-operatively with the support of the specialist endocrine team [58]. Alternatively, subcutaneous basal insulin may be used at a dose equivalent to the background insulin dose administered over 24 hours on the pump.

There are a few considerations when planning to continue insulin pumps intra-operatively. It is generally recommended that pumps be removed for X-ray, CT, or MRI scanning; however, covering the pump with a lead shield may be sufficient for X-rays. The need for imaging intra-operatively is often pre-empted and subcutaneous insulin may be a good alternative to pump use in these circumstances. Additionally, electro-cautery and the presence of flammable anesthetic mixtures with oxygen or nitrous oxide in the operating room may affect the function of the pump, so the manufacturer's guidance should be reviewed and followed [59].

Foot Protection

Pressure damage leading to subsequent ulceration may begin within a few hours of sustained pressure; therefore repositioning has been advised at least every 2 hours intra-operatively where possible. An array of pressure relieving devices are available, from foam mattresses to inflatable heel supports, which can reduce the development of pressure ulcers by up to 70%. However, there is no single, recommended device [60] and most orthopedic units employ gel pads or inflatable air-boots. Limb surgery is discounted since the operated limb is mobile intra-operatively.

Antibiotics

The role for peri-operative antibiotic prophylaxis in joint arthroplasty is well documented [61, 62]. People who are morbidly obese have differences in antibiotic pharmacodynamics and pharmacokinetics, making their efficacy less predictable in these people. Obesity is associated with increased rates of surgical site infection and studies by Dowsey and Choong have shown it to be an independent risk factor for peri-prosthetic infection at both hip and knee [63, 64]. As a significant proportion of people with type 2 diabetes will be obese, weight-adjusted dosing should be considered.

A few antibiotics have been studied in this population, including aminoglycosides, vancomycin, daptomycin, and linezolid. Weight-adjusted antibiotic dosing is not widely practiced in the UK or recommended in the guidance; however, the additional risk of obesity is considered in the dosing advice in Australian and US guidance. The American Association of Surgeons (AAOS) recommend weight-adjusted dosing for a range of antibiotics with a double dose of 2g cephalexin for patients over 80kg [65].

Post-operative Period

Managing Medication

Post-operatively, diet and usual diabetes medications should be restarted as soon as possible; however, there are a few oral agents for which clinical circumstances should be considered before reinstating. Metformin carries a risk of lactic acidosis, particularly in those with renal insufficiency. It should be omitted in patients who develop acute kidney injury until renal function returns to near baseline or eGRF is above 30 mL/min/1.73m^2. It should also be withheld in sepsis, congestive cardiac failure, and significant hepatic impairment, all of which may be associated with hypoxia increasing the risk of lactic acidosis. Thiazolidinediones such as pioglitazone should not be restarted if significant fluid retention or congestive cardiac failure have developed or when there are liver function abnormalities. In patients who have not resumed a normal diet, sulphonylureas such as gliclazide may be withheld because of their insulin secretory effects with potential for causing hypoglycemia. A smaller dose may be initiated and titrated up as oral intake returns to normal. A cautious re-introduction should also be considered where there has been a kidney injury, as reduced renal excretion can further augment and prolong hypoglycemia. Recent studies have demonstrated the safety and efficacy of DPP4 inhibitors, the gliptins, in people with mild to moderate hyperglycemia (200 mg/dl) [66]. In view of the potential problems with sulphonylureas, it is likely that the use of these agents will become more widespread.

Insulin infusions should continue until eating has resumed. On recommencing usual insulin treatment, the subcutaneous insulin dose should be administered 30 minutes prior to discontinuing the intravenous infusion, which has a 5–10 minute half-life to minimize the risk of DKA and glucose excursions.

Treating Hyperglycemia

Following surgery, management of hyperglycemia remains important both for people with diabetes and those with stress-induced hyperglycemia. Due to its breadth of usability, insulin remains the main agent for controlling hyperglycemia for in-hospital patients, and can be used regardless of comorbidities or altered clinical states such as impaired renal function and decompensated cardiac failure. Correction doses of insulin may be used in insulin-naïve people, but titrating doses of subcutaneous insulin referred to in the US as sliding scale are not advised. A recent meta-analysis demonstrated these corrective subcutaneous doses do not offer tighter glycemic control for hospitalized patients and are associated with higher rates of hyperglycemia than a range of other regimes without any significant reduction in length of hospital stay [67]. Due to these observed increases in glucose variability, the subcutaneous 'sliding scale' should not be used as the sole method of glycemic control, but may still be used to supplement other regimes.

Hypoglycemia

Hypoglycemia is unpleasant for patients and associated with higher mortality rates and longer hospital length of stay. It is important to remain vigilant to this risk and check capillary glucose in patients in whom an altered mental state may otherwise be attributed to delirium or drowsiness secondary to concomitant analgesia following surgery. With its associated risks, hypoglycemia can be a barrier to intensifying glucose treatment.

In the case of missed meals or interrupted nutrition, nurse driven protocols and automated management decision tools for the omission of sulphonylureas and prandial insulin should be implemented locally to reduce the risk of iatrogenic hypoglycemia and standardize care.

Specialist Teams

It is increasingly common for elderly orthopedic patients to be managed by an orthogeriatrician to focus on the medical aspects of care across the peri-operative period. While this has improved the overall medical treatment, the specific impact for quality of care for people with diabetes has not been studied. Specialist diabetes nursing teams often have a lower threshold for discharge and can considerably reduce length of stay for elective procedures with significant cost-saving implications [68]. Their input at key points in the peri-operative pathway has been shown to be beneficial, and clear pathways for pre-operative referral and post-operative involvement should be developed locally.

Special Circumstances

Steroids

Steroid injections are an important adjunct in managing musculoskeletal diseases. Intra-articular injections are most frequently carried out for osteo-arthritis [69], with the knee joint the most common site of injection, followed by shoulder, wrist, ankle, and elbow joints [70]. This route allows symptomatic relief whilst minimizing systemic corticosteroid effects. However, due to concerns over peri-prosthetic infection, their use is often avoided within 3 months of elective surgery [71].

Synthetic steroids mimic endogenous glucocorticoid, binding to the nuclear glucocorticoid receptor, affecting transcription of anti-inflammatory mediators. These effects may last for months. The effects of intra-articular steroid injections on the

hypothalamic-pituitary-adrenal axis have been most widely studied [72], but they may also affect glucose metabolism in a similar manner to oral steroids. This effect is exerted in a number of ways from increased insulin resistance to direct effects on pancreatic beta cell function. The resulting hyperglycemia may be asymptomatic or result in osmotic symptoms and fatigue. It often resolves spontaneously, but if persistent after steroid withdrawal, it is termed steroid induced diabetes.

The few studies examining the effect of intra-articular steroid injection on glycemic control suggest that there are only short-term effects, which vary depending on the site and type of injection [73, 74]. While the hyperglycemic effects are generally not sustained long enough to affect injection site elective orthopedic surgery due restrictions imposed by infection risk, it is worth noting that there may be an impact on glucose for up to 5 days following injection [73]. Therefore, people with previously controlled type 2 diabetes should have home glucose monitoring if elective surgery of another joint is planned with 2 weeks of steroid injection or closely monitored if emergency surgery is required.

The JBDS advise measuring glucose at least once daily, preferably prior to the evening meal, in those given steroids not known to have diabetes and if above 12 mmol/L(216 mg/dL), treating to maintain glucose levels between 6 and 10, accepting a pragmatic range of 4–12 mmol/l. They suggest HbA1C be measured in patients at high risk of steroid-induced diabetes, and a baseline level should be taken in those with pre-existing diabetes prior to commencement of steroids [75].

It is recommended to increase the frequency of glucose monitoring to 4 times a day and to commence treatment for 2 consecutive glucose readings above 12 mmol/L. For hyperglycemia resulting from intra-articular steroid injection, as with multiple daily steroid doses, oral agents are unlikely to control the hyperglycemia, and a subcutaneous insulin regime is preferred. A pragmatic approach would be to commence basal insulin and titrate this according to glucose values. In this case, a morning NPH insulin such as humulin I or insulatard is suggested, starting at 10 units daily titrating up by 10–20% every 24 hours until glucose readings are on target [75]. The local community diabetes team may be contacted for further advice and support.

Emergency Surgery

People with diabetes are more likely to require emergency orthopedic procedures for a number of reasons. Hypoglycemia and peripheral neuropathy increase the likelihood of falls, and bone mineral density is affected, particularly in those with type 1 diabetes, increasing the fracture risk further. The orthopedic surgeon may also be involved in the management of diabetic foot emergencies depending on the local service setup.

In the emergency setting, glycemic control remains crucial to reducing post-operative complications; however, the clinical situation restricts the time to fully optimize patients. In these settings, intravenous insulin given as a variable rate infusion remains the most effective way to achieve normoglycemia in the peri-operative period. The local protocol often advises continuation of the usual background insulin for those on basal insulin to facilitate prompt return to a normal regime postoperatively.

Where possible, DKA should be treated as a priority and the fluid and electrolyte disturbances of HHS should be reduced or corrected prior to surgery.

Conclusions

People with diabetes require particular consideration in planning orthopedic surgery. It can be difficult to put guidelines into practice across the multistep peri-operative process; however, significant improvements in care, with patient benefits and cost saving implications are possible. Specialist in-patient teams who can examine local processes, along with design and implementation of clear local pathways across the surgical process are key in minimizing the harm to this vulnerable group of patients.

Compliance with Ethical Standards

Conflict of Interest Funke Akiboye and Gerry Rayman declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent The study cited as reference 44 was conducted as a service improvement project and was carried out with approval from the trust in accordance with local policy.

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CHAPTER 6

Developing the diabetes perioperative passport

In order to address the challenges of diabetes care throughout the perioperative journey, the DICE team had sought to inform and empower patients in the process. To this end, a patient held booklet was produced, similar to the maternity booklet or folder that is widely used for women to hold along their antenatal journey. The passport, like the maternity booklet, would be taken to each visit and accompany the patient to admission for surgery.

The passport was developed with input from diabetes service users who formed a steering committee. Staff usability was also kept in mind with two groups of pre-assessment nurses from general surgery and orthopaedics invited to be involved in its development with varying success.

A working booklet was then piloted with the patients and staff from the two preassessment nursing groups approached and feedback was sought. Patient feedback regarding the passport was positive and has been published in a short report (appendix 1). The patient feedback was presented to the pre-assessment nurses and focus groups were carried out to understand their perception of the passport and address any challenges to implementing it, particularly in the group of orthopaedic preassessment nurses. The focus group exploration of this implementation challenge in the clinical setting forms the bases of this chapter.

Chapter 6: Evaluating Implementation of the Diabetes Perioperative Passport: A qualitative focus group study

Improving diabetes care in the perioperative pathway had been addressed at a number of levels. As a research fellow I has spoken with anaesthetists and presented a diabetes specialists perspective on the challenges of glycaemic control perioperatively. I and other members of the DICE team had also spoken with surgeons across the surgical specialities about the importance of diabetes inpatient care and introduced the idea of the perioperative passport, which may be handed to the patient when they are accepted for surgery. It proved difficult to engage the consultants in surgical and anaesthetic groups in adopting changes in practice despite the recognised importance. It was interesting to me to note that team efforts to implement the perioperative passport in preassessment was received differently between two groups of nurses, one who see orthopaedic patients and the other who see a range of surgical specialities from ear, nose and throat to colorectal. The impetus for this research came from my observations of this differential uptake. I used this to define the research question and designed the study choosing focus groups as an appropriate way to examine this. I wrote the topic guide and planned the most efficient and practical way for the focus groups to be carried out. I then co-facilitated them along with the DICE project manager. As the researcher I went on to transcribe and locate relevant frameworks to analyse the resulting data with supervisor guidance. I interpreted the findings and wrote the manuscript within.

Evaluating Implementation of the Diabetes Perioperative Passport: A qualitative focus group study

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Abstract

Aims

To examine the factors affecting implementation of an empowerment tool for patients with diabetes in two surgical groups within a single district general hospital

Background

A perioperative passport was developed to improve care of people with diabetes undergoing elective surgery by equipping patients with a hand-held summary of their care needs. Two surgical groups were approached to be involved in developing and piloting this novel technology with contrasting results.

Design

A qualitative study using focus groups to examine factors affecting staff engagement in implementing the diabetes perioperative passport.

Methods

Two focus group were conducted in 2017 with pre-operative nurses in the departments of orthopaedics and general surgery of an NHS trust (N= 8). Audio-taped group discussions were transcribed, and the data coded and analysed to identify themes.

Findings

The general surgical nurse group generally supported each other's views and comments. They were enthused about the passport throughout. In contrast, the orthopaedic specialist nurse group had initial reservations about implementing the passport, but as the focus group unfolded, they moved from sharing individual views to finding commonalities and became more engaged and motivated to use the passport.

Conclusion

Focus groups are a practical and efficient tool to conduct within the usual working environment of an NHS hospital. In addition to capturing information about the challenges to implementation they may serve as a crucial implementation tool where evidence-based practice has not been adopted.

Impact

This is the first study carried out in the NHS setting highlighting the benefit of focus groups as a practical implementation tool.

Keywords

Focus groups, facilitators and barriers, implementation, diabetes, empowerment, passport

Contributions to literature

- Diabetes is managed in the outpatient setting with care focusing on education and patient empowerment.
- Barriers for implementation of empowerment tools have not been fully explored.
- This study suggests the implementation of empowerment tools may pose an additional challenge to more specialist groups.
- It demonstrates that focus groups are practical and efficient and may also have utility in the implementation process beyond identifying the barriers to embedding a new technology.
- These findings contribute to the small body of evidence on the implementation of empowerment tools and highlight the benefit of focus groups as a useful tool in the implementation process.

Introduction

European health care systems are currently facing multiple challenges. People are living longer and together with improvements in care this has resulted in a rising burden of chronic disease. There is now an increasing need for innovation to continue to deliver effective, safe care despite these pressures and limitations.

Diabetes is one such chronic condition which is growing in prevalence, with 3.9 million people diagnosed in the UK; this number is estimated rise to over 5.3 million by 2025 (1; 2). It accounts for 10% of the NHS budget with a significant portion of these costs related to hospitalisation (3). People with diabetes are more likely to be

admitted to hospital both for medical reasons and for surgical procedures than those without the condition (4). The patient journey for surgery from referral, through surgical and pre-assessment clinics, admission and theatre to recovery and discharge home is complex and involves a range of healthcare professionals. Diabetes adds a further challenge to this perioperative pathway; however no single healthcare professional specifically focuses on diabetes management, despite the poorer outcomes to surgery associated with sub-optimal glucose control (5).There is opportunity for innovations to improve care with potential cost savings. The management of diabetes in the community has moved from a doctor centred to a more individualised and patient centred approach with education and empowerment at its core (6). Education for inpatients with diabetes is usually delivered by diabetes specialist nurses; However, hospitalisation often results in the patients handing over access to food and medication and ultimately their diabetes care to non-specialists as 22% of hospitals in England and Wales do not currently have dedicated diabetes nurses (7). With 1 in 7 inpatients affected by diabetes, novel ways to provide education to patients and empower them in the hospital setting must be developed (7). It is also crucial that trained non-specialists are able to deliver these innovations.

Even when innovations are evidence based and shown to improve care, their implementation in the NHS can be difficult with variable adoption into routine practice (8). The National Institute for Clinical Excellence (NICE) highlights 5 main barriers to implementation: awareness and knowledge, skills, acceptance and beliefs, motivation and practicalities (9). They stress that staff delivering the care need to be aware of the need for change; they must be trained where necessary to adopt the new technology. In order for this to be successful, they have to believe that they are able to deliver the innovation and that it will make a positive clinical difference and it must be adequately resourced in terms of personnel and time (9).

Despite the pressing need to innovate in the health service, strategies for implementation are inconsistently employed in practice. Furthermore, if implementation is unsuccessful it is not routine practice to evaluate the reasons why to address these factors. However, exploration of the reasons for failure to adopt an innovation could provide the key to integrating a new technology into routine practice.

Background to the problem

History of problem

A novel perioperative passport was designed to empower patients and improve care. This A5 ring-bound folder provides information for patients with diabetes on what to expect at each stage of the perioperative journey and what they could do to help manage their condition. In addition to patient information, the passport has sections for staff to fill in including information relating to their care such as weight, BP and HbA1c, enabling staff to document key information for the patient and illustrate any differences from the usual targets for these parameters. The aim was for people with diabetes to carry this patient-held record, literally taking their diabetes care in their own hands, to each professional contact from pre-surgical assessment to discharge. Example pages are shown in Box1.

The two largest pre-operative surgical nursing groups in the hospital were approached to participate in developing the passport at its inception and piloting the tool once produced. The project and pilot were enthusiastically taken up by a general surgical group; however, when it came to extending the pilot to a second surgical department in orthopaedics, implementation proved more challenging.

As part of the usual perioperative pathway, both groups assess the safety of patients to proceed with surgery and inform those with diabetes of risks of poor glycaemic control and any adjustments to make to their medication. A diabetes medication information leaflet is among the information both groups can distribute to appropriate patients. Participating nurses were asked to deliver the passport during their existing pre-assessment appointment and use it to provide a structured explanation of the patient's role in their own care, emphasising the importance of good glycaemic control from initial contact to discharge. Observations routinely recorded at this stage such as blood pressure, weight and HbA1c should also be entered on the passport. At home, the patient could familiarise themselves with what to expect prior to hospitalisation and bring in anything that would help with their glycaemic control around surgery, documenting their usual eating and treatment routines in the passport. Before and after surgery, the passport would be used by ward staff to treat and help patients manage their glucose levels; a discharge checklist empowers the patient to ensure that they are being discharged safely.

The experienced band 8 lead nurse of the general surgical nurse (GSN) group played a key role in the design and development of the passport, ensuring it would be usable and relevant to the broad range of surgical specialities managed by her team. Once developed the passport was presented to the GSN group with guidance and training provided on how to use it in daily practice. Additionally, they were asked as part of the pilot to feed back about its usefulness and content in practice; they were informed we would also ask for feedback from patients. Conversely, the orthopaedic surgical nurse (OSN) group did not participate in developing the passport but were approached again to pilot it with their patient group and provide feedback on its utility.

In order to prepare the GSN group for implementation of the passport, there was a session to present the passport to them and train them in using it attended by around 7 nurses. They were actively encouraged by their service lead to incorporate it into their consultations and shown how this would work in practice. It was more difficult to address the OSN group all together and following initial efforts to involve them in development of the passport a number of visits were made to their shared office over the course of several weeks to catch them individually to explain the passport and encourage them to issue it to their patients. Although hospital data indicated that the largest volume of elective surgery on people with diabetes in the trust was carried out in orthopaedics, the OSN group did not manage to hand out the passport to any patients. Following this, the decision was made after several months for the inpatient diabetes specialist nursing team to post the passports out to orthopaedic patients directly with a brief contact phone call explaining how to use it. This enabled patient feedback to be captured from orthopaedic patients.

Initially, we aimed to explore acceptability and feasibility of delivering the passport. An additional research question emerged from the observation of the differing responses to the opportunity to develop and pilot the perioperative passports between the OSN and GSN groups within a single hospital which is the main focus of this article. It is uncommon to have the opportunity to gain feedback from non-responders in research, however this is crucial for successful implementation of evidenced technologies (10) . This study therefore uses focus groups to explore the utility and practicality of implementing the diabetes perioperative passport aiming to extend its use to the OSN group. The groups also form a ‘case study’ of differences in organisational culture at the same trust and provide an insight into the ways in which these differences can shape the

implementation of an intervention. These insights are valuable for the planning and rolling out of interventions throughout the NHS.

Aims/Use of focus groups

This article focuses on the challenges experienced by orthopaedic specialist nurses in implementing the diabetes perioperative passport in their clinical work in comparison to the group of general surgical pre-assessment nurses. As these differences were observed within the same trust, an exploration of the groups' differing work cultures and challenges was of greater interest than larger structural barriers which the GSN group had overcome. Qualitative research lends itself well to this research question as it aims to explore the reasons why there were differences in involvement with the passport between the groups.

The focus group methodology involves facilitated discussion between colleagues sharing their views on the passport and enables a collective voice of each of the groups to be heard, drawing out opinions on adopting this initiative in the nurses' respective clinical areas. It was important to note the differences in the structure of the teams and observe the group dynamics that may account for their contrasting responses to the passport. and observe the way participants communicated and interacted to influence each other within the discussion.

Ethical considerations

An email and written information sheet outlining the aim of the research and assuring participants that their responses would be anonymised was distributed to nurses. To allow both groups to freely voice their opinions we presented patient feedback on the passport and asked for staff to consider whether it would work in its current state in their clinical area. This approach was also chosen to minimise a perception of being judged and resultant distress especially for the group who did not implement the passport.

The project received ethical approval from the University of Birmingham.

The researchers' role

FA worked in the trust as a diabetes research fellow which involved promoting initiatives set up by the diabetes team and collecting data on impact. FA and the passport project manager, EP, met the OSNs individually to show them the passport, invite them to hand it out and reinforce the need for data gathering from their patient group.

EP was involved in developing the passport, promoting and educating nurses on its use and co-facilitating in the focus groups with FA.

Methods

Participants

The GSN group comprised 3 participants with 5 OSNs in attendance.

Research site location

The study was carried out at district general hospital with a sizable orthopaedic department taking elective surgery from the surrounding areas.

Focus groups

The groups were carried out in each group's respective clinical/ office space for over lunch for comfort, convenience and practicality.

The focus groups were conducted over around 45 minutes with three sections:

Overview and feedback on the passport

EP presented a brief overview of the challenges for the patient with diabetes in navigating the surgical pathway, highlighting the impetus for developing the passport. Patients' feedback on the passport was presented by PowerPoint; this has been reported separately (11). Participants were free to ask questions.

Reviewing the passport

Passports were distributed at the beginning of the focus groups giving participants an opportunity to see its layout and finish, and refer to it during the presentation.

Exploring usability and applicability

The main focus group was conducted using a semi-structured topic guide (see appendix 1) to explore staff attitudes to the passport exploring whether and how they felt they could incorporate it into their clinical practice.

Analysis

The focus groups were transcribed, and two coding cycles applied to the transcripts. The first cycle used both in-vivo coding (using participants' own words) and process coding to elicit the nurses' perspectives on the passport and to allow the interaction of individuals to be explored (12). Memos of the researcher's thoughts and observations made during the first coding cycle were fed into the second coding cycle along with the in-vivo and process codes. In the second cycle, the focus was on the dynamics within the group. Therefore, gerunds such as agreeing, reinforcing and questioning increasingly emerged in this phase. This phase integrated first cycle codes and coding of the researcher's memos in order to develop further themes from the data.

The emergent themes were applied to appropriate frameworks. As the themes from the in-vivo coding were largely nurses' understanding of the passport and challenges they faced in implementing it in their department, they were first mapped to a comprehensive summary of the known barriers and facilitators taken from a systematic review on implementation of technologies in the hospital setting (13). Themes from the second phase will be discussed in relation to differences between the two groups and the group dynamics.

Results

Group structure

The structure of the GSN and OSN groups differ. The OSN group were experienced nurses (band 6-8) working with a named orthopaedic consultant, their associated anaesthetist and designated secretary. Each OSN therefore specialised in a joint or limb area for example hip and knee. While there may be some cross cover of duties at times, there is no leader or hierarchy within the group of OSNs. The GSNs were a small group of Band 3-5 nurses led by a dynamic and experienced lead nurse on the cusp of retirement who was the point of contact for a wide range of surgical teams and anaesthetists. Regular meetings allowed information, changes and concerns to be cascaded to the more junior nursing team. They all pre-assess patients from a range of surgical specialities.

The participants represented a pragmatic sample of available pre-assessment nurses on a given day for both groups. The OSN group comprised a significant portion of the whole group with 5 nurses, while a smaller sample of 3 nurses participated from the GSN group. The lead nurse from the GSN group who had been heavily involved in development of the passport had retired at the time of interview and was therefore not in attendance.

Emergent themes

The themes emerging from the first round of coding the OSN and GSN transcript were mainly barriers and facilitators of implementation such as lack of time. These themes mapped well onto categories from a systematic review of staff reported barriers and facilitators to the implementation hospital-based intervention (13). This provided a valuable framework to display the key areas reported by the nurses during the focus groups in the wider context of implementation within hospitals. The 12 categories identified in the systematic review are displayed, with key domains highlighted in bold within Table 1.

There were:

1. Environmental context, particularly staff workload and time

2. Culture – attitude to change, motivation, champions and role models
3. Staff commitment and attitude- need and ownership
4. Role identity
5. Skills, ability and confidence

Table 1.

This table summarises the broad categories (system, staff and environment) and areas within these categories found to be barriers and facilitators to implementation in a recent systematic review (13). The subdomains highlighted in this study are indicated in bold.

	Domain and description	sub-domain examples
SYSTEM		
	Environmental context Physical, structural resources of the context, along with its processes and personal resources	**IT, staff, time, workload**
	Culture System culture, beliefs and behaviours in relation to change and staffing roles	**Attitude to change, commitment and motivation, flexibility of roles/trust, champions/role models**
	Communication processes Online and in-person communication methods	Processes within the context
	External requirements External pressures or expectations	Reporting, standards, guidelines
STAFF		
	Staff commitment and attitudes micro-level beliefs, attitudes and behaviours toward change in general, and the intervention	**Perceived validity/need, ownership, perceived efficiency of the intervention**
	Understanding/ awareness Understanding the aims and methodology of the intervention	Understanding the goals of the intervention, and of the processes/ mechanics
	Role identity Beliefs and attitudes towards work role and responsibilities	**Flexibility, responsibility**

	Skills, ability, confidence Sense of capacity to carry out the tasks of the intervention, managing barriers posed by the target population and their work environment	**Ability andconfidence to engage patients, to carry out the intervention, to manage stress/competing priorities/ patient barriers**
INTERVENTION		
	Ease of integration How well the intervention "fits" with the current system, resources and needs of the population and context	Complexity, cost and resources required acceptability/suitability to system, staff and patients
	Face validity/ evidence base Is the intervention is grounded in solid evidence	Theory and evidence
	Safety/legal/ ethical concerns	Patient or staff safety; medico-legal concerns
	Supportive components components of the intervention which support and facilitate change	Education/training provided, marketing/awareness, audit/feedback, end user involvement

Data analysis

Similarities between groups

The themes emerging from the groups highlight the perceived strengths and weaknesses of the passport from a nursing perspective and identify the facilitators and barriers to its implementation in both pre-assessment clinics.

The areas the nurses in both groups expressed similar views or approaches on the passport were:

- Appreciation of benefit of passport to patients
- Importance of an up to date and comprehensive document

Quotes illustrating these areas of agreement are shown in table 2.

Illustrative quotes for the barriers and facilitators expressed in both groups are displayed in the categories and subdomains they mapped to in table 2.

Table 2 Mapped illustrative quotes

Factor	Illustrative quotes
SYSTEM	
Environmental context	Workload: GSN- if we give it [passport] to all diabetic patients…I would imagine there's quite a few… OSN- It would be every diabetic patient… OSN- we would have to fill this in as well as our charts… it will take a little bit more time to do that… Time: GSN- We're limited for time and I don't think this [passport] takes up a huge chunk of time. OSN- we really, really need to know who the diabetic patients are so we could have an extra 10 minutes.
Culture	Attitude toward change: OSN- Is it [passport] more work…that's the main stumbling block with introducing anything new. System level commitment: OSN- he [surgeon] is so inflexible…he's a lovely man, but inflexible. Champions: GSN- It would be nice if other departments got to know about it [passport]… if we just start it up…
STAFF	
Staff commitment and attitude	Attitude toward the intervention: GSN- Better than what we've got [i.e. generic leaflets], yes by far…more attractive as well…

	OSN- To be honest this [passport] is all we need to give them… Beliefs regarding the need for intervention: GNS- We often used to get comments like "how will my diabetes be managed, you know, while I'm in hospital." Motivation: GSN- I'm eager to do one [give out/ explain the passport] with someone with diabetes staying overnight 'cause I've got type 1 diabetes as well. GSN- Anything that's gonna help… to improve or stabilise their condition. OSN-[nurse gives example of a patient who shouted at her after she called to delay his surgery due to sub-optimal glycaemic control and felt written guidance for him would have supported her in this task.] "When I phone him her was really aggressive. Actually if he had this booklet…" "it's good for us as well." Ownership: OSN- As long as the nurses on the ward know about it [passport] … GSN- I'd be happy to fill in one of these for all patients, if that's the way it's going to go.
Role identity	Staff role identity: OSN- Who are you expecting to do the diabetes check list?
Skills, ability, confidence	Confidence to deliver the passport: OSN- They would have questions… you can't say don't ask me any questions GSN- Quite easy for us to do our bit [complete the health professional sections of the passport] GSN- …it's all there already so you're literally just taking the patient through.

	Patient related barriers: OSN- …if you put too much stuff in they just stop reading it. GSN- …they would only have this themselves…it's how reliable the patient is … on the day…so it's trying to make sure the two are […coordinated]. Time management: OSN- We would have to fill this out as well as our charts [pause] which is fine…

Differences between groups

Despite universal appreciation of the passport as beneficial and a well-designed tool, there were areas in which the groups differed in their willingness to utilise it in their routine practice.

These centred on the work required and the nurses' ability to find time and have the resources to implement it in practice. Contrasting attitudes are highlighted in in table 2.

There were 4 key areas where groups differed:

- Ease of use/ time burden
- Culture and attitude to change
- Staff role identity
- Skills/ ability/ confidence

Ease of use/ time burden

The GSN group did not feel that the passport significantly added to their workload while the OSNs expressed that this would be a duplication of some information they had in leaflets for patients with diabetes. Some felt that the additional explanations and documentation of observations in the passport could be time-consuming and patients with diabetes would therefore require longer appointments.

Culture and attitude to change

There also were differences in culture between the groups and among individuals in the OSN group in their attitude to change. The GSN group maintained their senior nurse's openness to change as shown by her involvement in developing the passport and encouraging staff to use it. In the OSN group a nurse who offered to hand them out to her patients initially was a lone voice in the focus group.

Staff role identity

Advocacy vs Authority

There is a contrast between the two nursing groups in the roles the nurses played in supporting the patient journey. The advocacy role is more evident from the outset with the GSN nurses.

In care settings, advocacy is a process of supporting and enabling people to express their views and concerns, access information and services, explore their options and promote their responsibilities (14). GSNs spoke a lot from a hypothetical patient perspective "if I was a patient…" and portrayed the passport as useful and informative for patients. This perhaps reflects their junior level and consequently the more limited experience they could draw on. Their role is not to explain the surgery in detail to the patient, but rather prepare them for it, giving patients an idea what to expect in hospital and signposting where necessary. It is worth noting that one of the nurses in the GSN focus group was a staff nurse with type 1 diabetes. She had not used the passport but spoke enthusiastically, sometimes from a personal viewpoint, of living with the condition and expressed she felt it was a good idea for patients. Nurses drew on empathic advocacy about patients being the expert of their disease which was likely influenced by her presence: "they're the best people to manage their condition, aren't they".

The OSN group nurses had specialist knowledge in their limb or joint area and the information they give patients is tailored with some pathways structured slightly differently. They also describe a way of working which is specific to the consultant(s) they work with; consequently, information can be provided not only about the latest evidence for that type of surgery, but also about the operating surgeon's and anaesthetist's usual practice. "we're going to be giving our hip and knee patients a high carb drink to take home… on the enhanced recovery programme". This implied a different approach to patients attending pre-assessment. They

take a more directive approach, informing patients what to expect and enforcing what was required of them. They appeared to carry more responsibility for ensuring perioperative readiness and had the power to delay surgery if this was not delivered. "…when I saw him at pre-admission I told him that if his …HbA1c weren't better…we couldn't do surgery". Taking on this authoritative role is challenging at times: "you don't want to tell them they need to lose loads of weight…"

Later in the focus group discussion the OSNs also mentioned their role as patient advocates. This is 35 minutes into the group compared with just 6 minutes for the GSN's, who alluded to this role enthusiastically and frequently.

Skills, ability, confidence

The OSN group suggested that the passport was a good idea; however there was a large perceived impact on their time and workload. This is in contrast to the GSN group who felt it was quick and easy to use in everyday practice. This difference may have, in part, been a reflection of lower confidence they had in explaining diabetes care to patients in the detail that the passport appeared to require.

Changes during focus group

During the process of coding, differences in responses between the groups became apparent. Additionally, there were some themes where OSNs as a group appeared to change their position as the focus group progressed. The domains of the barriers and facilitators framework where these changes were most marked were motivation and group identity.

1. Motivation

While the OSN group appreciated it was a useful intervention for patients, this statement was generally caveated by the question of what would be expected of them in implementing it emphasising that this would affect their workload. This perception appeared to shift after one of the nurses shared a story of a personal challenge with an aggressive patient whose surgery had to be delayed due to poor glucose control. The

personal benefit to the nurses of using the passport was illustrated and there were no further objections to its utility.

2. Team identity

The structural differences in the set-up of the two nursing groups is apparent early in their interactions. The GSNs were speaking as peers doing the same work who could ask each other for advice and support. They shared practice and affirmed each other's statements and observations. The GSN group were quite vocal in their comradery making affirmative comments and statements throughout.

Initially, the OSN nurses spoke about their individual joint or limb practice or quirks of the surgeon they worked closely with, which did not relate to the practice of others in the group. They gave each other space to speak and respected the position of their peers, but were not seeking to support each other through the initial interactions. As the focus group progressed, the OSN group appeared to become more cohesive in emphasising and expanding on what their colleagues had just stated.

There was a noticeable difference towards the latter part of the OSN focus group. The pivot point appeared to be strong words from a senior nurse about the workload and time pressures. She expressed a collective will to help patients, but also the shared feeling of time scarcity. With this clearly and openly stated the nurses appeared able to move past their individual objections to the passport and started brainstorming how it may be implemented at other stages in the pathway to allow patients to benefit whilst limiting the impact on their own workload: "we do a hip and knee group, perhaps you could come and hand it out there".

The behaviour change model helps categorise what is observed during the focus group. The main change appears to be centred around scenario-based risk taking. Over the course of the discussion the nurses in both groups offered issues they had encountered or noticed themselves with patient care. Finally, the single story shared in the OSN group around this challenging patient scenario was an act of storytelling or Scenario-based risk-taking. It was powerful for both groups in connecting them as a team with shared experiences and particularly with the OSN group helped address their collective concerns and provided a potential individual motivation to use the passport.

Discussion

People with diabetes are educated and empowered to facilitate daily self-care to manage their condition. This patient-held booklet encourages patients to retain ownership of their condition while encountering a range of professionals throughout their perioperative journey.

Our findings indicate that although two groups within the same organisation may share positive views about a new intervention, the attitude to and subsequent success of implementation is highly dependent on other factors. Crucial barriers were noted under the sub-domains of staff commitment and attitudes to change, role identity and skills, ability and confidence with differences in the perceived extra workload or time commitment required to administer the passport. The reasons for this contrast appears to, in part, be related to differences in the composition and structure of the teams.

The group structure and presence of a team with a shared purpose and clear leadership is known to be an important factor in implementation (15). Change orientated leadership has been shown to aid learning and psychological safety within a team (16). While the GSNs benefited from this in their group structure: the OSN group worked alongside their consultants and so did not; this structure also appeared to link to their professional identity.

In the GSN group staff had a role identity as patient advocate which fed into the belief that the passport addressed patient needs and that they could reasonably incorporate it into their practice. For the OSNs, the empowering purpose of the passport was perhaps more challenging to the existing role identity of a more specialised position; they also required additional time to incorporate it into their role.

The place of professional role identity in the implementation of empowerment tools has not previously been explored in the literature. However, a study by Dijkstra and colleagues noted more resistance embedding an empowerment tool among consultant physicians compared to diabetes nurses (17). There were mixed views among the consultant group with lack of motivation and lack of time cited as barriers to implementation in keeping with our study, perhaps indicating that they identified their value as their expertise and specialist knowledge in a similar way to the OSN group. The differing response of the staff groups to this tool suggests that role identity can actas either a barrier or facilitator (13).

Conversely, rather than having fixed identities, staff can also take on a range of roles, for example in achieving patient adherence. Following a year-long ethnographic study roles adopted by doctors in treating patients with diabetes were categorised as educators, detectives, negotiators, salesmen, cheerleaders and policemen depending on how they interacted with the patient and the strategies they employed to encourage adherence e.g. praising for achievement of goals or warning of complications (18). It is interesting to note the more authoritarian style of the OSN group nurses is in line with the "policeman" role Lutfey describes. This is in contrast to the more "cheerleading" role taken by the GSNs. This observation raises the question of the role adopted by the person delivering an intervention in the success of implementation including the role of a group's collective dominant working style. The most effective style of implementing in each group may be influenced by the dominant style they adopt in clinical practice. It may be that HCPs groups who have a predominantly authoritative or "policeman" way of working respond best to the same style they adopt or a very contrasting style such as negotiator or detective whereas cheerleaders, who already share a collective agenda, might respond best to a policemen approach. This is a potential area for further exploration.

Beyond highlighting the dynamics of the groups, perhaps the most interesting finding in this study was the role of the focus group in facilitating change, which is otherwise poorly described in the literature. Despite definitions of focus groups as opportunities to observe the interaction between participants and the shared development of thoughts and ideas is rarely reported. Instead, researchers appear to use them as time efficient simultaneous individual interviews. This discrepancy has been explored in a meta-analysis by Belziles et al which explains the key role of group cohesion in this process. "If participants manage to establish common ground they behave more as a small group (co-creating the narrative as they go along);if they do not…they will behave more as individuals "expressing private views (19). This again highlights the importance of the differences in structure of the groups, but goes some way to explaining the place of story-telling in producing these changes in the OSN group during the focus group. The power of story-telling was also noted in some studies included in Geerlig's review where sharing success stories influenced in staff's readiness for change (13). Importantly, these findings reinforce the potential usefulness of focus groups not only in gathering information about the barriers for implementation, but additionally and crucially as a behaviour change tool in their own right.

Reflections

The primary researcher FA was promoting the passport with nurses and in this role recognises that codes may have been assigned to the two groups reflecting some of the resistance encountered from the OSN group prior to the focus group. There did not appear to be a particular anxiety in the group about speaking openly however as many in the group had previously been approached directly there may have been some initial guarding in their responses.

The observation of the emerging narrative between focus group participants is thought to originate from the researcher's assumption that the participants co-construct meaning rather than participants sharing their pre-formed opinions. This approach is associated with more socially-orientated researchers (19).

Strengths and Limitations

The study is limited in the size of the GSN group which had only 3 participants for practical reasons. Although this is less than usual for a focus group it is not likely to have had a significant impact on the view shared as the participants in this group had a very similar approach.

There were 5 participants in the OSN group which was appropriate as a larger group may have silenced some colleagues from active participation. In both groups every participant contributed to the discussion.

The senior nurse who set up the passport had since retired and was not therefore involved in the focus groups which allowed the small group of GSNs to speak freely about their views on the passport.

Conclusions and implications

The data shows that evidence-based tools can be challenging to implement within a department even if the tool is regarded by staff as beneficial for patients. Perceived lack of time and motivation are barriers to the implementation of empowerment tools which may be more notable in staff with specialist and authoritative role identities. However, this may be modified by addressing other areas such as skill and patient related barriers.

Another useful finding is related to the use of focus groups. They are routinely conducted to assess the barriers implementing an evidence-based technology in a time pressured and busy hospital setting. Moreover,

through sharing of stories or scenario-based risk taking, focus groups can be vehicle for behaviour change and may aid implementation in areas or departments where adoption of a tool has previously been less successful. The ways in which professionals involved in implementation in the healthcare setting tailor their strategy to different groups is a potential area for further research.

List of abbreviations

Declarations

Author contributions

Funke Akiboye and Krish Nirantharakumar developed the concept of the study with input from Antje Lindenmeyer. Funke Akiboye designed the study with supervision of Antje Lindenmeyer. Funke Akiboye carried out the focus group, transcribed and analysed the data and prepared the manuscript under the supervision of Antje Lindenmeyer. Emma Page was involved conducting the focus groups and the designing and implementation of the passport with Funke Akiboye and under the guidance and close supervision Gerry Rayman. All authors reviewed, contributed to and approved the final manuscript.

Competing interests

The authors have no conflicts of interests. No external funding was received to conduct this research.

Ethics approval and consent to participate

This research was approved by University of Birmingham's ethics committee and written consent was gained from participants.

Funding

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Consent to publication

Not applicable to this research.

Availability of data and materials

Transcripts are not available in public repository for participant confidentiality, but portions are available on reasonable request from the first author.

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List of abbreviations

OSN - Orthopaedic specialist nurse

GSN - General surgical nurse

HCP - Health care professional

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Appendix

1. Semi-structured Discussion Guide for perioperative passport focus group:

1. Tell us your current role and how long you have been working in surgery.
2. Explanation of how the passport was developed.
3. Staff feedback from looking at the passport in session
4. Positive and negative things about the passport
5. Features to change/add.
6. Overall satisfaction with the current passport.
7. Presentation of perioperative passport pilot results
8. Any usability issues in practice for staff
9. Factors that may affect acceptability and adoption of the passport.
10. Willingness to use the passport in the future and why.
    - When appropriate to use the passport?
    - When and why not appropriate to use the passport?
    - Wishes/ suggestions for improvements.
11. Any other thoughts about the passport.
12. Is there anything we should have talked about, but didn't?

Give a big thanks to all participants!

Appendix for Chapter 6

DIABETICMedicine

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Short Report: Care Delivery

Perioperative passport: empowering people with diabetes along their surgical journey

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Abstract

Aim To determine whether a handheld 'perioperative passport' could improve the experience of perioperative care for people with diabetes and overcome some of the communication issues commonly identified in inpatient extracts.

Methods Individuals with diabetes undergoing elective surgery requiring at least an overnight stay were identified via a customized information technology system. Those allocated to the passport group were given the perioperative passport before their hospital admission. A 26-item questionnaire was completed after surgery by 50 participants in the passport group (mean age 69 years) and by 35 participants with diabetes who followed the usual surgical pathway (mean age 70 years). In addition, the former group had a structured interview about their experience of the passport.

Results The prevalence of those who reported having received prior information about their expected diabetes care was 35% in the control group vs 92% in the passport group ($P<0.001$). The passport group found the information given significantly more helpful ($P<0.001$), including the advice on medication adjustment (P 0.008). Furthermore, those with the passport were more involved in planning their diabetes care ($P<0.001$), less anxious whilst in hospital ($P<0.044$) and better prepared to manage their diabetes on discharge ($P\leq0.001$). The mean length of hospital stay was shorter in the passport group, although the difference did not reach significance (4.4 vs 6.5 days; $P<0.058$). Content analysis indicated that the passport was well liked and innovative.

Conclusion Our data indicate that the perioperative passport is effective in both informing and involving people in their diabetes care throughout the perioperative period.

Diabet. Med. 34, 1737 1741 (2017)

Introduction

The Perioperative pathway is often a multi step process which can be particularly challenging to people with diabetes, with many experiencing anxiety and dissatisfaction with their care [1]. The Joint British Diabetes Societies (JBDS) guidelines state the perioperative process should be seamless and that the patient should be involved in planning at all stages [2], yet failure of communication is often identified as a common issue in inpatient experiences [3] along with difficulty in identifying high risk patients prior to surgery [2]. Primary care referrals often lack detail about diabetes, such as the patient's recent HbA_{1c} concentration or their glucose medication, and some fail to make mention of diabetes at all in the referral letter [4].

It is known that people's ability to self manage is integral to successful diabetes management [5]. People undergoing elective surgery who manage their diabetes every day in the community often find it disempowering when hospital staff, many of whom have little diabetes experience, prevent them taking decisions about their diabetes management [2]. In one Dutch study conducted in six hospitals, only half the participants reported that they had received information about perioperative diabetes treatment and only one third of the participants received any information about the effect of surgery on blood glucose. Most participants were unaware of their diabetes perioperative caregiver or of who to contact in case of diabetes related problems during their hospital stay. Half felt able to ask questions and only one third felt involved in the decision making regarding their diabetes treatment [6].

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What's new?

- We developed a perioperative passport as a novel approach to help overcome the disempowerment and poor communication that is often experienced by people with diabetes undergoing elective surgery.
- The passport contained essential information pertaining to a surgical inpatient stay and addressed common questions that patients may ask about their care.
- Quantitative and qualitative methods showed that the perioperative passport was effective in involving and informing people with diabetes undergoing elective surgery.
- The perioperative passport has the potential to be widely adopted by other National Health Service Trusts wishing to enhance their perioperative pathway for elective patients with diabetes.

The JBDS perioperative guidance has tried to address many of the issues experienced by people with diabetes undergoing surgery, but many health trusts report difficulty introducing this guidance or in achieving successful improvements. A study in the Netherlands looked at implementing a multifaceted improvement strategy across six hospitals but found that this had limited impact on the quality of perioperative diabetes care [7].

These difficulties prompted us to consider a new strategy in which people with diabetes are empowered through their perioperative journey. We took the definition of empowerment as being a patient centred, collaborative approach tailored to match the fundamental realities of diabetes care [8].

To empower patients we came up with the concept of a handheld 'perioperative passport' containing essential information pertaining to a surgical inpatient stay and questions that patients may wish to ask about their care. The 'passport' was put together by a working group of diabetes specialists, surgical healthcare professionals and the Ipswich Hospital Diabetes Patient User Group. The passport was also approved by the hospital reading group to make sure it was set at a suitable reading age.

The passport was designed for the patient to take to each of the stages in the perioperative journey and to be used as a collaborative tool for patients and healthcare professionals. The passport was broken down into the stages of the perioperative journey. It included information for the patient to fill in about their diabetes care, information for healthcare professionals to fill in to inform the patient of aspects of their preadmission care and information about what to expect in terms of diabetes care whilst in hospital. Pages relating to each of the three aspects of care were colour coded for ease of identification (Fig. 1 and Appendix S1).

We aimed to determine whether the passport would help people with diabetes undergoing elective surgery feel better informed and more involved in their diabetes care at various stages of the perioperative process.

Participants and Methods

Study design

This comparative study was carried out at Ipswich Hospital NHS Trust and compared the experience of patients undergoing usual diabetes elective care with those who were also given a perioperative diabetes passport. Usual care included being given pre printed instructions produced by the diabetes team at the pre assessment clinic specifically addressing preadmission eating and drinking and diabetes medication adjustment and being prescribed a bedside snack by the

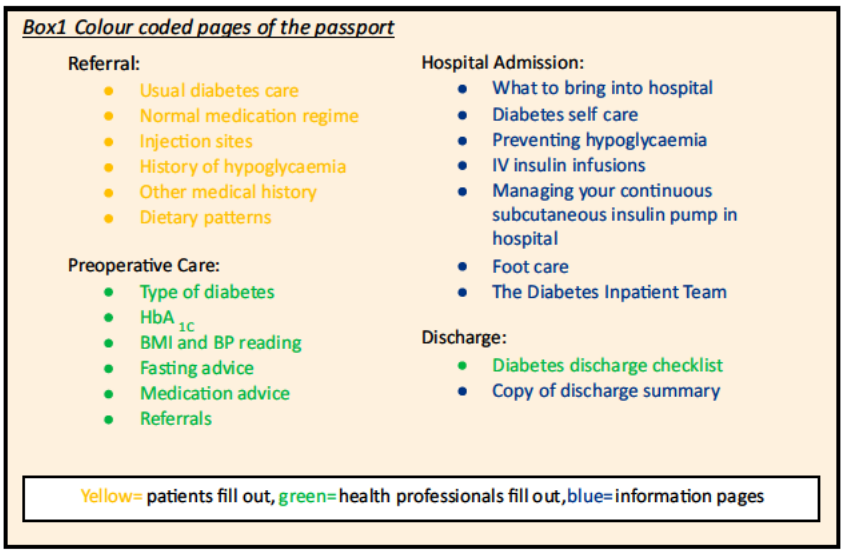

FIGURE 1 Colour coded pages of the perioperative passport.

diabetes inpatient specialist nurses on admission. The diabetes inpatient nurses were available to patients in both groups during their admission.

This study was deemed to be an assessment of service improvement and not research by the Trust's Research and Governance Committee. Approval to conduct the study was thus sought from and given by the Hospital's Audit Committee.

Participants

To be included in the study, participants had to be undergoing elective general, orthopaedic or spinal surgery and require at least an overnight stay. Participants were identified using a customized information technology system when listed for surgery and were randomly allocated to a group via simple random allocation using computer software. Those who no longer required surgery or who opted to not proceed with surgery were then excluded. More patients in the passport group went on to have surgery, resulting in 53 participants in the passport group and 39 in the non passport group being given the questionnaire.

Procedures

The passport group received an introductory telephone call from the diabetes nurse team before receiving the passport in the post. The passport was explained to them and they were asked to fill out the relevant sections in the passport and bring this to all appointments and the admission. Before its implementation, preoperative staff, relevant ward nurses, junior doctors and consultants were made aware of the passport at *ad hoc* briefing sessions.

We could find no standard validated measure to evaluate the various aspects of care associated with the diabetes passport. The team generated a number of questions which, after discussion and feedback from patients, were finalised at 26 items. The questions comprised some dichotomous items, while the majority required the participants to rate various aspects of care on a 10 point scale. The items were presented to participants in the form of a three part questionnaire, as follows: 1) experience before coming to hospital; 2) experiences whilst in hospital; and 3) experiences of discharge (Appendix S2). On discharge, both groups were given this questionnaire which was returned via post, thus minimizing the interpersonal contact between researcher and participant. Participants in the passport group were given the option to take part in a structured telephone interview once they had completed the questionnaire. Fifteen participants opted to do this.

Analyses

The quantitative data from the questionnaire items requiring participants to respond on a 10 point scale were analysed using ANOVA and data presented as means and SD values. Categorical data were analysed using chi squared tests. The interview data were analysed by a psychologist (S.J.) using content analysis with an implicit coding structure.

Results

The two groups were similar in age (passport group: 68.6 ± 10.4 years; usual care group: 70.3± 12.8 years) and in gender split (passport group: 42% women; usual care group 41% women). Loss to follow up rate was 6% in the passport group and 10% in the usual care group. Loss to follow up included those not returning the questionnaire or who opted to no longer participate.

Experiences before coming into hospital

There was no difference between the groups in how well informed they felt about the actual surgical procedure (9.5±0.99 vs 9.0±1.6; P=0.11), but the passport group reported being better informed of the importance of having good diabetes control in the weeks prior to surgery (9.4 ±1.5 vs 4.6±3.7; P=0.0001). More participants in the passport group reported receiving information about their expected diabetes care prior to their surgery (92% vs 35%; P<0.0001). The passport group gave a higher rating to the value of the information given (8.9±1.7 vs 4.6±3.7; P<0.0001), including the information on pre surgery medication adjustments (9.4±1.5 vs 8.1±2.5; P=0.008) and on what they could eat or drink in the hours before surgery (9.4±1.2 vs 8.7±1.9; P=0.036).

Experiences during time in hospital

Those given the passport felt more involved in planning their diabetes care (8.3±2.4 vs 5.0±3.3; P<0.0001) and less anxious whilst in hospital (1.8 vs 2.8; P =0.0437). The majority of participants were allowed to monitor their own blood glucose whilst in hospital if they opted to, but two participants in the passport group and four in the usual care group were prevented from doing so. There was just one participant in each group who wished to but was not allowed to give their own insulin, although two participants in the usual care group were unsure if they were able to. Of those who were on insulin, 86% were able to decide their own dose in the passport group and 81% in the usual care group (P=0.791). Of those in the passport group, 8% received an i.v. infusion compared with 14% of those receiving usual care (P=0.353). Those who did have an i.v. infusion felt better informed of its purpose in the passport group, although this difference was not significant (8.7± 1.5 vs 5.8±4.4; P=0.243).

Participants in the passport group were more aware of the inpatient diabetes team (76% vs 40%; P=0.0008), but there was no difference in visits made by the inpatient diabetes team to the two groups.

One issue identified by some participants during the interviews was that some ward nurses were not aware of the passport.

Experiences after discharge

Participants in the passport group felt better prepared to manage their diabetes care on discharge (9.2±1.6 vs 7.0±3.3; P=0.0015). The mean length of hospital stay in the passport group, although shorter, was not significantly different (4.4±2.6 days vs 6.5±7.1; P=0.059). There was no significant difference in how satisfied the participants were with their overall care (9 ±1.9 vs 8.4±2.2) or in the likelihood that they would recommend the hospital to family or friends (9±2.1 vs 8.7±1.7).

Content analysis indicated that the passport was well liked by 100% of the participants, met their needs and was easy to fill in. All interviewed said they would use it again. Users of the passport also reported they felt more prepared for surgery and that the passport answered all of their questions. Feedback also included that it may be of less use for expert patients who are very assertive and confident, but very useful for people with diabetes going into hospital for the first time, or those who have been recently diagnosed or who have poor control of their diabetes.

Discussion

The perioperative passport was found to be effective in both informing and involving people undergoing elective surgery about their diabetes care throughout the perioperative period in comparison with existing pathways. Those receiving the passport reported being significantly better informed pre operatively of the importance of having good diabetes control before surgery. People who have good diabetes control before surgery are less likely to develop postoperative complications, so it seems imperative that this is communi cated clearly to patients early on in the pathway. This is of even more importance when we take into account that such information is not always communicated fully during the general practitioner referral process.

There was a vast difference between the groups in those who reported having received information about their diabetes perioperative care. This is not to say that those in the non passport group did not receive any information; indeed, the perioperative information sheets they had been given were produced by the diabetes team, but the fact that the majority could not recall receiving such information would suggest that this format is not effective. Furthermore, when comparing those who did recall receiving prior information, participants with the passport found the infor mation more helpful as it included essential information on medication adjustment and eating and drinking before surgery. Without such information patients are at risk of adverse events, cancellation and delayed procedures.

When in hospital the results seem to suggest that partic ipants in the passport group had a better understanding of their diabetes management. Those participants who had an i.v. infusion in the passport group rated the understanding of the purpose behind it as higher, although this difference did not reach significance. The awareness of the inpatient team was significantly higher in the passport group, although this did not seem to have an influence on the frequency of visits

The results also indicate that the passport can be helpful in establishing a more collaborative approach in perioperative diabetes management, with patients feeling more involved in their diabetes care, less anxious whilst in hospital and better prepared to manage their diabetes on discharge. The results are noteworthy when coupled with the knowledge that when people are involved in their own healthcare the decisions made are often better, health outcomes improve, and resources are allocated more efficiently [9].

Although we did not set out to measure direct health outcomes, it was noticeable that the length of stay was shorter in the passport cohort, albeit not significantly. Larger numbers may be able to determine whether the passport can also have an effect on important outcomes such as cancel lation rates, length of stay, readmissions and diabetes related harms.

Strengths of the present study include the integration of the intervention into routine clinical care. The passport did not require staff to make big changes to routine care pathways, but instead empowered the patient to take back some control of their perioperative diabetes care. Further strengths include the recruitment from multiple diverse surgical disciplines and the method of randomization of participants will have helped to reduce selection and allocation bias.

It could be argued that one of the limitations of the study is the lack of validation of the questionnaire; however, as we were reporting results by each item and not by calculating the questionnaire total, and the same questions were used for both groups, this should not have an effect on the validity of the study. A further limitation is that the results may have been influenced by hospital staff's enthusiasm with regard to the intervention tool rather than the use of the passport *per se*. We tried to minimize this by posting out the passport direct from the diabetes centre so that staff contact with the passport on admission was initiated by the patient. In fact we have evidence from the interview data that staff enthusiasm was even lacking at times as it was identified that some ward staff did not always engage with the passport. We believe this lack of engagement is largely attributable to not being able to introduce the passport to all ward staff because of shift patterns and agency staff who may have therefore not been aware of its content or purpose.

Loss to follow up was slightly higher in the usual care group and this, along with the difference in group size, may have introduced bias. The groups became unbalanced because more patients in the usual care group did not proceed to surgery. There was a necessity for randomization

to take place before exclusion because the passport needed to be sent out as soon as patients were listed for surgery, but it was not known at that point who would and would not go on to have surgery after listing.

In summary, the perioperative passport achieved its aims of helping people with diabetes undergoing elective surgery feel better informed, better communicated with, more involved, less anxious and more empowered in their diabetes care throughout the perioperative process. Crucially the passport was well liked by participants and deemed easy to use, important factors in patients' engagement with the passport. We plan to roll out the passport within other surgical departments at Ipswich Hospital to further enhance the diabetes perioperative pathway and to conduct a larger study to measure clinical outcomes and evaluate the cost effectiveness of the passport. We believe that the passport has the potential to be widely adopted by other NHS Trusts wishing to enhance their perioperative pathway for people with diabetes.

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Competing interests

None declared.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. The Diabetes Perioperative Passport.
Appendix S2. Diabetes questionnaire for patients undergoing surgery.

CHAPTER 7

Discussion

Contents overview

The final chapter provides an overview of: the key findings of each of the initial objectives of the thesis, how these findings fit into the clinical context and relate to current literature, the strengths and limitations of the different methodologies utilised, the recommendations that emerge from the findings for this research and the potential implications of this research on practice and policy. Finally, I include a personal reflection on the impact of undertaking the thesis for me and implications on my future career as a clinician and postgraduate researcher.

Summary of key findings

The aims of this thesis were to explore the impact of a whole systems, nurse delivered approach to diabetes health care, the DICE project by investigating its effect on (1) length of stay, in-hospital mortality, readmissions and (2) in-hospital complications. Then (3) to review the broader impact of diabetes inpatient specialist nurses in the health care service today using systematic review. In parallel (4) to Develop and propose guidance on the management of hyperglycaemia and diabetes in the perioperative pathway, particularly in the orthopaedic setting and highlight points for specialist intervention and finally to (5) examine the challenges in implementing an empowerment tool in this pathway for diabetes in the hospital setting.

The impact of DICE

To address the many factors that disrupt the usual management of diabetes for patients admitted to hospital the DICE programme was designed as a multifaceted approach to

diabetes inpatient care as previously outlined. To the best of our knowledge this nurse delivered programme incorporating educational and technological patient identification tools is the most extensive and proactive approach to addressing the challenges of diabetes inpatient care.

In order to assess the effect of the programme accepted indicators of patient care were used, from both routinely collected Patient Administration System data and manually extracted bedside data.

Length of stay, mortality and readmission

Extraction and analysis of PAS data showed a significant reduction in length of stay on implementation of the DICE programme, with no change in mortality (55). The before and after data indicated a reduction in length of stay in all patients, with a relative ratio 0.89 (95%CI 0.83-0.97) for those with diabetes and 0.93 (0.90-0.96) for those without. However, the ITS analysis revealed that the reduction in those with diabetes was in excess of the reducing length of stay explained by background trend within the hospital for all patients. A reducing trend for mortality was seen using before and after analysis, however this was not evident in the robust ITS analysis which took into account background secular trends. Readmission at 30 days did not change significantly in the group using before and after analysis, however ITS found a rising background trend in all patients which was probably not attenuated by the DICE programme (1).

Complications and harms

The findings of this study show a reduction in hospital acquired infections as an aggregate measurement (OR 0.71, 95% CI 0.58-0.87) with the incidence of pneumonia reaching statistical significance as well as a significant reduction in foot ulcers. Drug errors were

significantly reduced with oral agent prescription and management errors OR 0.41 (95% CI 0.32-0.5) and 0.18 (95% CI 013-0.27) respectively, but the largest drug error reduction seen was in insulin management errors (OR 0.17 (95%CI 0.12-0.24). This was associated with a lower use of injectable hypoglycaemia treatment (OR 0.41:95%CI 0.23-0.77), likely as a result of reduction in hypoglycaemia.

The impact of diabetes inpatient specialist nurses on patient care

The systematic review identified 10 studies making objective measures of the of the impact of DISN on patient care, one RCT (2) and 9 before and after studies (1; 3; 4; 5; 6; 7; 8; 9; 10), with only 3 of these using ITS analysis, thus accounting for background secular trends (1; 5; 10). Length of stay was the most frequently reported outcome with a median reported reduction ranging from 0.5 to 3 days across the studies. Drug errors reduced by an average of 52% and post discharge glycaemic control was improved with HbA1c falling from 10.45% to 8.9% with DISN input (4). Patients were found to have higher patient satisfaction and improved knowledge (2). In hospital mortality was not significantly affected and there was a lack of data surrounding in-hospital complications (1).

The management of diabetes and hyperglycaemia in orthopaedic surgery

This review shows strong evidence for an association between hyperglycaemia and poor postoperative outcomes particularly for Surgical site infection, periprosthetic infection and mortality. There is limited evidence across other surgical specialities that improving glycaemic control perioperatively can attenuate these complications. In orthopaedic surgery there are additional considerations for the patient with diabetes. In lower limb surgery, particularly for patients with neuropathy the consequences of poor wound healing and superadded infection can be catastrophic, and in some instances require amputation.

Suggestions for optimisation of the patient with diabetes orthopaedic surgery are made and placed along the perioperative pathway at typically opportune moments. This decision tree may be considered a suggested pathway for patients with diabetes undergoing any major elective surgery. Local teams can utilise this to build on their current pathways to develop processes to improve care and safety in this at-risk group.

Implementation of the diabetes perioperative passport

The challenge of effectively piloting a perioperative diabetes passport in general surgical and orthopaedic preassessment areas provided an opportunity to examine the reasons for resistance. The GNS group were enthusiastic about the perioperative passport and supported each other's views and experiences throughout the discussion. The OSN group in contrast were initially more individualistic in their sharing, demonstrating their subspecialist expertise. As the focus group continued, they exchanged stories and found commonalities, cohesing as a group. Sharing their experiences also highlighted the potential benefits of the passport for them in clinical practice.

Results in relation to current literature

Below I outline the areas in which the studies that have contributed to this thesis support or contradict the current literature. As two of the chapters, 2 and 5 comprise reviews, the focus for these areas is on what these publications add to existing literature.

The current clinical context

First it is important to recognise that the health care system in the UK is under continual and increasing pressure. It is required to manage the rising demand on stretched services and

growing expectations of the public provision and care standards available. All this is under conditions of huge financial strain.

In response to these demands there have been some general shifts in the delivery of services. There has been a drive to move hospital services into the community with resulting national reduction in length of stay (11). It is therefore important that methods for analysis of change take the national trends and local variations into account.

There has been encouragement to adopt technology for delivery and monitoring of care processes. This has brought a number of opportunities such as electronic prescribing, however the constant innovation and expectation to integrate novel technologies into routine practice has caused change fatigue in many health professionals (12).

This thesis has re-examined the relevance and use of diabetes inpatient specialist nurses in the current climate, by reviewing the current literature and measuring the impact of a multifaceted approach to inpatient care utilising novel technology. It goes further to explore the barriers to introducing a new technology in the context of a system continuously evolving.

The clinical impact of the DICE programme and specialist nurse on care

Length of stay, readmissions and mortality

The measurement of the impact of diabetes inpatient nurses has been measured in several studies using length of stay, however the most recent of these was in 2008. With the trend towards shorter hospital stays nationwide it has not been clear whether the benefits of DISN would be seen in this era. The before and after analysis findings demonstrate this and the PAS data study goes further to highlight the limitations of this widely used methodology alone for assessing the impact of interventions. The findings are in keeping with previous

studies indicating that DISN reduce length of stay and can continue to do so in the current climate (1; 2; 3). The PAS study reveals a rising trend for readmissions, and this is noted elsewhere in the literature. The reducing trend in mortality in all patients may be a multifactorial change as a result of improved care and advanced care planning which allow more patients to die in their own homes or care homes in the community (13).

Harms and complications

This study uniquely provides data on the inpatient complications following the introduction of diabetes inpatient specialist nurses with a significant reduction in infective composite complications, foot ulcers and drug errors. A previous study by Umpierrez looked at the complication rates when tighter glycaemic control was adopted by use of a basal bolus regime compared to correctional doses of short acting insulin, four times a day in patients with type 2 diabetes undergoing surgery (24.3 and 8.6%; OR 3.39, 95% CI 1.5-7.65) (14). While this study is in agreement with our findings, it also suggests that the mechanism by which complication rates were reduced was predominantly due to improved glycaemic control. It is doubtful that this protocol, which was delivered in an American hospital could be adopted more widely in the pressured systems and staff we see in the NHS today. Like the DICE project, an adjustment towards such an approach is likely to require additional training for staff and ongoing support. The Umpierrez study, as many others, was however limited to surgical patients while our study add the impact of the DICE project across both medicine and surgery, making it more applicable to a whole hospital setting.

Systematic review of the impact of DISNs

The review is the first in addressing this specific question, providing a systematic overview of the objective measures which demonstrate the impact of DISNs. It agrees with a recent

hermeneutic review that looks at DISNs that included evidence from the community setting as well (15). In keeping the scope of our study focused on DISNs this systematic review enables a more robust appraisal of the evidence and updates the sources used in the hermeneutic with additional papers (1; 4). These studies are important in that they answer some of the questions raised in the hermeneutic review where the evidence was extrapolated from the community setting and bring the existing length of stay data into the current clinical context. The systematic review also highlighted the research gap of outcomes which is then addressed in the analysis of DICE bedside data (15).

Orthopaedic pathway

This comprehensive review of the literature considers the orthopaedic pathway and the impact of diabetes care and hyperglycaemia on inpatient care. It draws on the evidence available to form a practical and clinically applicable structure for improving care processes along the perioperative journey.

Perioperative passport

This study considers a number of factors in the implementation of a pilot for the perioperative passport. The data that emerged from the focus group supported established ideas that the adoption of innovation is influenced by the group structure and composition with change orientated leadership acting as facilitators (16).

There is limited literature studying the barriers and facilitators to the implementation of patient empowerment tools. The roles and identities participants take has been identified as a barrier to implementation previously, however this appears only to have been examined from the perspective of the health care professional with challenging patients. This study turns the mirror on the HCP.

In addition to identifying the factors contributing to non-participation in a pilot study for the perioperative passport, this research describes the finding that focus groups are a vehicle for progress of thought and a potential tool for behaviour change and implementation.

A unique quality of focus groups is the interaction between participants with methodological advice for conducting them emphasising the facilitators' role in enabling participant interaction rather than sequential questioning of group members. While this characteristic of focus groups is widely stated in the literature, the methods for analysis, reporting of this interaction and the uses of focus groups to utilise this feature are generally limited In the healthcare setting the use of focus groups is often data collection, particularly in conditions where there is stigma that may be reduced by the sharing of experiences with others in the disease group, exploring opinions or health or educational needs of patients or staff and identifying psychological issues or commonly used terminology (17).

Despite the description of the method as an interactive and iterative process for participants, the explicit use of focus groups as a behaviour change or implementation tool in non-responders has not previously explored to the best of our knowledge. This research offers a broader perspective on the potential uses for focus groups in the health care setting and suggests they may be of benefit in implementation in a non-responder group.

Strengths and Limitations

The limitations and areas for potential bias in each of the studies is detailed in their respective chapters. However, there are some overarching themes that run through the thesis which are outlined here.

Applicability and potential for recommendations

The DICE project was a real-life whole systems approach to improve care and as such it demonstrates that this nurse delivered system is practical to implement in our current health service. However, all hospitals have different local structures, and the many elements of the project may not fit well into the existing structures and pathways of all trusts. It is difficult to know with such a comprehensive implementation programme delivered and embedded over a 6-month period which of the interventions within the programme had the largest impact. This limits the ability to provide any particular group with recommendations on the best use of resources for the many interventions encompassed within the programme.

As is also demonstrated in chapter 5, the receptiveness of the staff and engagement with interventions which are perceived to add to their work-load may vary with the culture or identity of the hospital and groups within the hospital. The majority of the interventions were delivered by the DISNs with little input from other specialists. This is a strength of the study, however an engaged and innovative IT department was crucially necessary for many of the innovations and the absence of this in other hospitals may limit the practical transferability of the interventions encompassed in the programme.

These potential local restrictions allow further exploration of the impact of selecting the elements that may be implemented practically on inpatient care with the local processes in place and in line with the culture of the trust.

Data accuracy

The quality of the data recorded in in the PAS records and medical notes is a potential limitation of the study. Although medical records are a legal document the quality of the

data recorded is inconsistent. The information that is encompassed in the discharge summary informs the PAS data. The quality and completeness of this has been reported to vary due to differences in how clinicians and clinical coding staff classify diagnoses and procedures with error rates as high as 37% reported (18; 19). In recent years there have been significant efforts to improve this error rate, with an average rate of 7% measured across 40 UK hospitals in 2013/14 (20). Efforts to improve this further are ongoing with coding accuracy forming a stream of the "Get It Right First Time" (GIRFT) programme nationally.

Bias

Both the systematic review of specialist nurses and the orthopaedic review of specialist show areas where there are gaps in the literature. As it is not customary to register trials with intended outcome measures routinely, it is not apparent if the propensity for journals to report and record positive findings is likely to have created a publication bias in the data available. There is a move away from publication of positive findings alone in recent years.

The interventional studies looking at the impact of DICE and implementation of the passport were well conducted to reduce bias at each stage and in undertaking the research as part of a PhD the focus was more on learning and applying the best research practices rather than achieving publication. I believe this approach is a strength of this body of work.

In the planning of each studies a pragmatic or predetermined sample of patients or staff was taken minimising selection bias. For the DICE before and after studies objective, prespecified outcomes were measured and training provided to standardise the data collected by the group of nurses involved in this process. The study was also conducted over the same 6-month period (January to June) over two consecutive years to minimise the

impact of seasonal variation. This planning limited bias at the implementation stage of the DICE before and after studies. For the analysis the prespecified measured were reported with efforts to avoid subgroup analysis of data which was not prespecified.

Implications

This thesis examines the impact of a nurse delivered, multifaceted approach to diabetes inpatient care and gives insights into the challenges of implementation in the real-world setting. In addition to providing options for improving inpatient care it examines some of the methodologies used to measure outcomes in the health care setting and considers the applicability of these more widely.

Methodologies

Chapter 1 uses the two methodologies to examine LOS, mortality and readmissions. This study demonstrates the limitations of the before and after study. In using the additional method of ITS analysis, the background trend over several years is shown to reveal that mortality and readmissions continued to change at the same rate despite the DICE intervention. This highlights the benefit of ITS analysis in determining the impact of interventions. Furthermore, by comparing to the trends of the non-diabetic population we were able to account for potential generic interventions outside of DICE that may have led to the observed changes. It is hoped that with these demonstrated benefits there will be increasing uptake of this quasi-experimental methodology in the health care setting, increasing the understanding and accuracy of our analysis of interventions.

In Chapter 5, focus groups are used to determine the factors that contributed to the failure to implement the perioperative passport. As part of the process sharing experiences the

OSN group shifted their perception of the practical use of the passport and motivation towards distributing it. The use for focus groups for this process of changing someone's perspective in the implementation of a technology has the potential to broaden their use. While focus groups are currently used as intended in this study to gather information about facilitators and barriers to change, the observation of the change during the focus group repositions their practical use in the process of implementation in non-responder groups.

Clinical and research recommendations

Length of stay, mortality and readmissions

This study revealed the rising trend for readmissions, demonstrating the cost of this push for shorter length of stay. While length of stay is communicated as bed days it worth noting that the cost of a patient's admission is not equally spread across the stay. The initial phase of moving between the community, through the emergency department and on to the relevant admission or assessment unit before moving onto a ward carries the highest cost. The true financial cost of reducing length of stay in view of a rising readmission rate has yet to be investigated economically and is an area for potential future study.

DICE Bedside

This before and after study shows provides a positive signal for the benefit of a nurse delivered whole systems approach to diabetes inpatient care. Knowing the limitations of the study design open the same outcome up to further research with a randomised controlled trial, either within hospitals or by cohorting whole hospitals in cluster randomised controlled trials. It re-emphasises the importance of good glycaemic control in hospital and allows several strategies to achieve this.

Systematic review

This paper suggests ongoing benefit from employing diabetes inpatient nurses and the clinical data from the DICE project add to the clinical benefit of this. There are gaps in the data that would benefit from future study. Firstly, the impact of diabetes inpatient nurses on patient satisfaction in the current system where the emphasis is on brief and limited intervention within an increasingly short length of stay. The impact of DISN on staff was beyond the scope of this systematic review, however the growing incidence of diabetes and concerns over keeping non-specialist staff sufficiently up to date with the changing landscape of diabetes care suggests further research in this area is warranted. Indeed, it is a recommendation of this systematic review that education of non-specialist clinical staff in diabetes is a future priority for diabetes inpatient teams to safeguard patient care.

Perioperative care

Orthopaedic review and guideline

This article recommends examining local processes along the perioperative pathway which will reveal several instances where interventions can be made to optimise the perioperative condition of patients with diabetes. Reviewing the existing literature suggests that there are significant benefits to this and a guideline of the points of contact are laid out.

Perioperative passport focus groups

There are several interesting avenues for further study that this article brings up. As clinicians, the training emphasis is on gathering data and explaining findings. The skills related to influence are much less prioritised

and often delivered in leadership courses. Consequently, when technologies are implemented, the need is often expressed as data rather than positioned in alignment with the motivation of the group being asked to implement it. Story telling or scenario-based risk taking appeared to have a key role in transforming the perspective of the OSN in implementation of the perioperative passport. The focus group created the space for this facilitated discussion and was a crucial turning point for the OSN in lessening their resistance to implementing the passport. The recommendation is therefore that focus groups are used more widely in the implementation of new technologies, particularly where previous efforts have been unsuccessful. In addition to finding the barriers to the previous efforts to implement the technology they may act as a catalyst for change in the process.

Further work

This research adds to existing literature and lays a foundation for further research both within the DICE project and more widely for the impact of DISNs. The research questions that this thesis opens up for exploration can be considered as: extending the research for clarity and broader understanding of the impact of the DICE project implemented in 2014 and subsequently, and further questions the research has stimulated.

Expanding on the impact of DICE

The benefits of the relatively stable population in the region, and the use of the PAS dataset for interrupted time series analysis, have been demonstrated in Chapter 2 in the length of stay reductions following implementation of DICE. The use of this quasi-experimental analysis method may be applied to different populations within the DICE project to gain clarity on the differing impact of the DICE in different inpatient populations, for example,

medicine versus surgery. IST analysis would allow investigation of the impact of the fully implemented perioperative passport with these routinely measured care measures in general surgery and orthopaedic groups.

The collection of bedside data was a large undertaking for study within the DICE project. It generated a comprehensive dataset across medicine and surgery within the hospital. A measure of patient reported outcome measures (PROMS) has been collected within a general surgery for a number or years within the trust. The application of interrupted time series analysis to this surgical cohort on implementation of DICE would be a further potential application of this analytical tool and provide valuable information of the patient perspective of the impact of this nurse delivered service.

The positive findings within the analysis of bedside data offer an opportunity for a deeper understanding of the associations between improvements in drug errors and complications, length of stay and dysglycaemia. Linkage of these datasets for a combined analysis to examine correlations would add to our understanding Further work with these combined data to determine the economic impact of the DICE project would provide valuable information to explore the place for a nurse delivered whole systems approach to diabetes inpatient care in today's health service.

Further questions raised in the wider context

The systematic review reports good evidence that new or additional specialist nurses reduce length of stay. It reports limited evidence for reductions in drug errors and improvements in glycaemic control with new or additional DISNs. The specific roles undertaken by the nurses in these studies are an important area for further investigation to ensure that the DISN activities are optimised towards those most effectively impacting patient care outcomes.

There is a concern that the improvements in patient care produced by DISNs comes at the expense of lower staff confidence in managing inpatients with diabetes. It was noted during the scoping of this research and in the included studies, that the impact of DISN on non-specialist staff working patterns, competence and confidence was not measured or reported. These are crucial areas for further study to ensure that workforce is not deskilled in managing this increasingly prevalent condition. Similarly, patient satisfaction and confidence in the care they are receiving for their diabetes warrants re-evaluation as the trend towards reduced length of stay may leave patients with unanswered questions or concerns, unless conscious efforts to mitigate this are taken.

The narrative review of orthopaedic surgery also highlighted gaps in the literature as potential areas for further study. There has been insufficient study of the use of preoperative carbohydrate loading in patients with diabetes using insulin to encourage its use in the enhanced recovery programme. However, advances in continuous glucose monitoring may provide opportunities for this to be safely studied.

National guidance suggests that patients are actively involved in their perioperative care, however, efforts to pilot a passport intended to facilitate this were initially met with some resistance in the orthopaedic setting in the hospital where the study was carried out. The qualitative part of this research in Chapter 6 explores the reasons for this. It opens a discussion of the staff factors that may have contributed to, or hindered implementation, such as patient held empowerment tools. Further, detailed interviews to explore the differences in perceptions of patient empowerment tools in the workforce would build on this research and allow a more tailored approach to implementation in various staffing groups. The findings and impact of the focus group also make a case for their wider use in

the clinical setting in exploring reasons for failure of implementation and of novel technologies.

Personal implications for this research – researcher's journey

Undertaking this research, the presentation of it at conferences progressing to a consultant medical position has been a personal journey which has challenged me in unexpected ways. The lessons have been all the more powerful as societal and personal events have happened.

The broad mix of methods learnt and incorporated into this research have given me a broad understanding of research techniques and methodologies I may use for projects in the future.

Writing is a skill I don't feel I learned in school and when I was later diagnosed with dyslexia I knew that working towards a higher degree with a thesis would be a personal challenge. However, the practice of writing has helped me find my voice and I now put this towards my passion projects of writing a podcast "what the health" and song writing.

As a medic I have been used to working hard, but the grit that has to develop when preparing and working on a PhD is very different to the daily dopamine hit that motivates and sustains a career in medicine. I have though persisting with this thesis developed a resilience and different perspective on where I place my energies.

The exposure of presenting this research on the national and international stage at conferences has been a great experience for me but also been an inspiration to other black females who are both underrepresented in consultant medical positions and academia. I have had many black junior doctors encourage me with this feedback at conferences and in

the clinical setting. While I personally had no desire to be a role model, I realised the impact of my visibility when the Black Lives Matter movement erupted. With the platform and experience research had given me I was able to be an effective voice in my hospital.

Looking to the future, research has profoundly affected the way I view and approach life.

The broad mix of methods learnt and incorporated into this research have given me a broad understanding of research techniques and methodologies I may use for projects in the future.

This work has started me on a journey to understand the power of storytelling and to consider how I use it in my interactions, re-write and edit old stories that have become my identity and write my story going forward.

The opportunity to collaborate and have experienced and methodical collaborators to have worked with on other research during this time has been both productive and enjoyable for me. I hope to use the skills and connections I have gained to reach out.

I have would like to set myself up as an independent researcher working on projects for behaviour change across a variety of areas and craft a masterpiece life.

Conclusion

This thesis has demonstrated the benefits of diabetes inpatient nurses in delivering a whole systems approach to inpatient care. The studies undertaken both update existing literature, bringing the impact of these multiple interventions on outcomes such as LOS into the current clinical climate, and add breadth to the gaps in the literature by examining additional important outcomes such as in-hospital complications which were found to be reduced, in particular infections and foot ulcers. Additionally, this thesis highlights the

benefits of experimental processes such as comparative ITS analysis and focus groups in producing improved data analytics, less biased interpretation and in the case of the focus groups initiation of change in practice.

Finally, this thesis has been a personal journey for me, allowing me to grow in skills, network and resilience. With these skills I have gained I am better equipped to contribute more widely academically and in all areas of my life.

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