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ORIGINAL ARTICLE

Inpatient diabetes care: complexity, resilience and quality of care

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Abstract It is estimated that 10–15 % of UK hospital inpatients have diabetes. Poor glycemic control is a care quality problem that has been linked to organizational factors such as inadequate training, inadequate protocols, problems with communication and teamwork, and difficulty coordinating mealtimes. Interventions using specialist diabetes teams have been effective in addressing some of these problems and have led to increased staff and patient self-efficacy and reduced length of stay. The aim of this study was to investigate how inpatient diabetes care is delivered and how resilience is created and/or breaks down, and to identify the implications for quality improvement. In-depth interviews ($n = 32$) with diabetes specialist and non-specialist staff were conducted in an acute medical admissions environment in an 850-bed teaching hospital. The Critical Decision Method, a content-orientated knowledge elicitation technique, was adapted to guide interview schedules, which explored key decisions, gaps and discontinuities in care and strategies for work system improvement. Care is delivered through the coordination of a multilayered team of different professionals. Specialists provide expertise and problem solving through case-based reasoning using problem-solving skills acquired through past experience. Ward staff focus on processes and immediate patient needs and are more reliant on decision protocols. Gaps in care can occur and result in delays in referring to specialists and clinical inertia. Specialists are a key source of resilience in the system and bridge gaps by acting reactively to problems, proactively monitoring and anticipating problems, providing staff education, and patient support and education. Opportunities for supporting clinicians to bridge gaps in care were identified.

Keywords Cognitive systems engineering · Resilience engineering · Patient safety · Organizational complexity · Specialist teams · Inpatient diabetes care

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1 Introduction

Maintaining appropriate levels of blood glucose for diabetic inpatients has been described as a complex control task, involving the interdependence of many variables such as diet, activity, stress and medication (Klein and Lippa 2012; Klein and Meininger 2004). Moreover, there are multiple possible effective pathways for achieving optimal control, and the goals can change depending on lifestyle, age and situational contexts (Flach 2012; Klein and Lippa 2012; McHugh et al. 2011).

When this task has to be accomplished by a team of healthcare professionals for an inpatient admitted to

hospital with multiple comorbidities, all the organizational complexities of the hospital environment are added to those of glucose control. The need for quality improvement in inpatient diabetes care has been highlighted (Daultrey et al. 2011), and good standards are a priority for healthcare organizations (Department of Health 2001).

In this study we examined how diabetes care is delivered in the inpatient setting and the organizational and cognitive challenges for clinicians who provide this care. These topics are now discussed in more detail.

1.1 Inpatient diabetes management

It is estimated that 10 % of the NHS budget is spent on diabetes care with 10–15 % of those admitted to hospital having diabetes (rising to 20 % for those with conditions such as coronary heart disease; Diabetes UK 2010). The majority of these admissions are unrelated to diabetes, but subsequent diabetes issues may complicate their course.

Concerns about the standard of inpatient diabetes care have been raised by both diabetologists and patient groups (Clement et al. 2004; Diabetes UK 2009). Poorer outcomes can be found for hospital patients who are known to have diabetes, as well as those with undiagnosed diabetes and those with hospital-related hyperglycemia (Clement et al. 2004; Giangola et al. 2008). Poor glycemic control is also associated with longer time in hospital and associated costs (Smith et al. 2009).

There is recognition that organizational factors including low nursing staffing levels (McHugh et al. 2011) are implicated in less effective care (Bates et al. 2005). However, research investigating effective management of diabetes in inpatients has been limited, and there have been few studies reporting organizational interventions designed to improve care.

1.2 Specialist teams

The role of diabetes specialist nurses has broadened over the last two decades, evolving from primarily a patient education role to encompass complex clinical work such as prescribing, managing specialist clinics and specializing in particular clinical areas such as pediatrics (James et al. 2009; Yong et al. 2002).

Numerous studies have found that interventions by diabetes specialist nurses result in improved outcomes (Taylor et al. 2003), more stable blood glucose levels (Yong et al. 2002; Aubert et al. 1998), reduced length of stay (Aubert et al. 1998; Davies et al. 2001; Sampson et al. 2006; Ioannidis and Lau 2001) and increased patient knowledge and confidence (Davies et al. 2001). Courtenay et al. (2007), in a UK study across six wards in a district general hospital Trust, measured various indices (length of stay, patient self-reported knowledge and confidence) after the intervention of a Diabetic Specialist Nurse (DSN) prescriber and concluded that the intervention reduced prescribing errors, which had some effect on length of stay. A recent study found that despite the proliferation of diabetes specialist teams in hospitals in the UK, the care of diabetic inpatients was high risk, with many gaps in care including lack of protocols and guidelines, inappropriate treatment and lack of access to services (Sampson et al. 2007).

1.3 Barriers

Other studies have identified barriers to optimal glucose control, including clinical inertia, which describes a reluctance to initiate or intensify therapy when it is indicated (Clement et al. 2004; Giangola et al. 2008).

Clinical inertia arises for a number of reasons, including failure to identify signs that action is necessary, lack of confidence on the part of the clinician and fear of hypoglycemia (Giangola et al. 2008; Cook et al. 2007; Wild et al. 2007; Anger and Szumita 2006; Clement et al. 2004).

The complexity of treatment regimes and the multiple influences on glucose metabolism mean that clinicians are not always knowledgeable about insulin usage and best treatment options (Cook et al. 2007; Rubin et al. 2007) and may feel ill equipped to manage diabetic patients (Diabetes UK 2009; Rubin et al. 2007). The question of when to prescribe insulin, how much, at what interval and by what method is highly complex. Clinicians are frequently unfamiliar with existing hospital guidelines on insulin regimes or do not use them (Cook et al. 2007, 2008).

Interventions to improve the quality of inpatient diabetes care have focused on strategies for improving clinical effectiveness, for example, standardization of protocols and procedures to improve patient outcomes (Roman and Chassin 2001; Reynolds et al. 2007). Nevertheless, improvement efforts should be based on a comprehensive understanding of how work is organized and achieved, to ensure that planned interventions target the situated, complex problems experienced by healthcare workers (Nemeth et al. 2007).

Organizational and systems barriers to optimal care include poor communication between staff, lack of multidisciplinary working, inadequate training and lack of specialist care at weekends (Giangola et al. 2008) as well as challenges in patient self-management. Klein and Lippa (2012) used a cognitive systems engineering perspective and identified gaps between what is required of self-managing patients and the information they receive in educational programs.

Organizational problems like delays at mealtimes and unexpected changes in timings of procedures (e.g., surgery) have also been cited as barriers to optimal glycemic control (Cook et al. 2007; Diabetes UK 2009; Courtenay et al. 2007).

1.4 Resilience engineering

Improving organizational outcomes has traditionally been approached from a 'high reliability' perspective (Roberts and Libuser 1993) preoccupied with discrete events and their causes. Arguably, such methods are problematic because (a) systems are complex and not easily reducible (Hollnagel 2004; Wallace and Ross 2006) and (b) system components are coupled and produce unexpected interactions (Cook and Rasmussen 2005; Perrow 1984).

An alternative approach, which we employ in this study, is resilience engineering, an emerging theoretical perspective that emphasizes the capacity of a system to adapt safely to changing conditions. Resilience can be defined as the ability of a system to self-correct and adapt to disturbances so that normal operations can be maintained even when unexpected conditions are encountered (Hollnagel 2010) and is viewed as an emergent feature of the work system (Nemeth et al. 2008).

Research emerging from this perspective often involves learning about how the work system operates and how work is accomplished successfully under varying conditions in order to identify ways to increase resilience (Hollnagel 2010). The focus therefore moves beyond human error (Woods and Cook 2002; Wallace and Ross 2006) toward understanding the adaptive capacity of the system and how people anticipate, deal with and recover from difficult demands and challenging conditions (Hollnagel 2009; Woods and Wreathall 2006).

There are several advantages of using this theoretical perspective. The emerging consensus in this area is that safety is strengthened by enabling workers to adapt safely to changing conditions, through a deep understanding of the whole system, rather than by controlling what they do (Nemeth et al. 2011). Resilience engineering allows holistic understanding of the work system, thus avoiding the difficulties of reductionist approaches that study isolated system components and cannot therefore take into account interactions between system components. Additionally, interactions between system components, which often give rise to unexpected or unintended consequences, can be studied as important features of the system, which provide insights into how performance can be improved. The perspective also implies that problems are multifactorial, emerging from interactions rather than being caused by a single antecedent (Dekker et al. 2011). This is consistent with the view that healthcare systems are complex in that they are open, continually changing in response to their environment, have multiple components and nonlinear processes and are not fully specifiable (Dekker et al. 2012).

Resilience engineering developed from conceptual roots in ecological resilience (see Holling 1996 for a discussion of ecological resilience). However, it has a particular aim of creating robust and flexible organizational processes, with a focus on learning and adaptation at system level as a means to improve safety (Barach and Johnson 2006). It emphasizes the importance of understanding how work is actually accomplished, rather than how it is assumed to take place, or how it is represented in procedures and protocols. This approach has much in common with the tradition of studying technical work, which has a long history (Barley and Orr 1997; Nemeth et al. 2007).

Resilience engineering for organizations thus generates insights into how interdependent teams cope with the complexity of clinical work, and how multiple interacting factors can combine to create problems in care quality (Patterson et al. 2006a, b). It provides a rich framework for deep understanding of technical work, which in turn can inform the development of interventions to improve quality (Nemeth et al. 2008; Patterson et al. 2006a, b).

Resilience engineering is an emerging and developing research paradigm (Mendonca 2008). As interest increases via a multiplicity of approaches, its definition, core concepts and methods are still the subject of debate among researchers. See, for example, recent research on indicators of resilience, which has some overlap with the resilience engineering perspective (McManus et al. 2007).

Other researchers have approached the study of resilience from the perspective of gaps in care and how these are bridged in clinical practice (Nemeth et al. 2008; Cook et al. 2000). According to this perspective, gaps in care result from the complexity of work processes and systems, and healthcare practitioners continually strive to bridge these gaps. Understanding the nature of gaps, how workers bridge them and sometimes fail, reveals how resilience is created and how it can be bolstered (Patterson et al. 2006a, b). In this study we used the concept of gaps and bridges to analyze data on how inpatient diabetes care is delivered and to identify potential interventions to improve the quality of care.

1.5 Aims and objectives

The aim of this study was to (a) investigate and describe how the clinical micro-system of inpatient diabetes care provision operates, by mapping key clinical staff roles, responsibilities and interactions; (b) identify how resilience is created and how it breaks down and (c) provide a basis for designing interventions to improve care.

We defined the system under investigation as the delivery of diabetes care to inpatients; the management of diabetes in primary care, in the community and on an outpatient basis was outside the scope of this study. A key objective was to identify specific staff needs for support, education, advice or other factors that would improve their ability to care for diabetic inpatients.

We used the Critical Decision Method (CDM; Hoffman et al. 1998), adapted for this study, to elicit information during in-depth interviews with diabetes specialist and non-specialist staff.

2 Methods

2.1 Setting

The hospital is an 850-bedded teaching hospital located in a busy urban center. It has a diabetes specialist team which provides expertise and support to ward staff in managing inpatients and outpatient multidisciplinary clinics; consultants, specialist registrars and diabetes specialist nurses can be contacted within office hours to support a range of functions including diagnosis, discharge planning, treatment initiation and titration, managing diabetes complications and meeting patient educational needs. Our study took place on two adult general acute admission wards, which provide medical care for up to 72 h after admission. The diabetes specialist team provides proactive review of all diabetic patients on these wards, and therefore, interaction between ward staff and the specialist team occurred frequently.

2.2 Participants

As we wished to examine systems from multiple perspectives, non-proportional quota sampling was used to ensure that specialists and non-specialists of varying seniority and experience levels were represented. It has been argued that for small sample sizes (typically in studies using intensive qualitative methods), the bias from quota sampling is less dangerous than the lack of precision introduced by small probability samples (Deville 1991). The sample included diabetes specialist nurses, specialist doctors, ward nurses and non-specialist doctors. Final numbers of staff interviewed by role and department are shown in Table 1.

2.3 Procedures

The study was approved by University ethical review. Fully informed written consent (under the terms of the Data Protection Act, 1998) was obtained from participants after they read an information sheet that disclosed the study aims, what would be involved (including interview duration, transcribing, risks and benefits), confidentiality and anonymity, freedom to withdraw from participation and full contact details for the research team for further information, complaints and feedback.

Interviews were conducted during April and May 2011. These were digitally recorded and transcribed verbatim to files for electronic processing.

Table 1 Participants ($n = 32$)

Department	Role	*n*
Specialist diabetes team	Diabetes specialist nurses	8
	Specialty registrars; diabetes (doctors)	2
	Consultants: diabetes and endocrinology	3
Medical admissions unit (MAU)	Nurses	7
	Consultants; acute medicine specialists	2
	Specialty registrars; acute medicine (doctors)	2
	Junior doctors in training	3
	Clinical lead; acute medicine	1
	Ward manager	1
	Healthcare assistants	3
Total		32

2.4 Interview schedules

Information about work systems can be elicited using cognitive task analysis techniques (Hoffman and Militello 2008). The CDM (Hoffman et al. 1998) is one such method. It is a retrospective knowledge elicitation technique, which is designed to gather information about critical events and decisions. For example, the CDM may illuminate systems by identifying cues that experts may pick up on and novices miss (Klein et al. 1989). Cook et al. (2000) outline how analysis of incidents can identify gaps and areas of vulnerability in complex care systems.

Non-routine or 'critical' events (Flanagan 1954) are assumed to be the 'richest source of data about the capabilities of highly skilled personnel' (Klein et al. 1989, p. 465). However, as an aim of the study was to understand how work was normally accomplished, we adapted the CDM methodology by first eliciting a description of *routine work* before focusing on critical or non-routine events and decisions. Prompts were designed to be similar in each case.

Participants were asked to describe in turn a routine case of diabetic care which represented for them their normal working environment (usually with no adverse outcome) and then a non-routine (critical) case of special interest which raised particular challenges and/or issues. The aim was to identify cases that would shed light on how the system of care worked well, how it was stressed or tested and how resilience was maintained or broke down.

In line with recommendations from Klein et al. (1989), we elicited relatively unstructured accounts of events to establish a timeline while taking notes of critical decisions in context for further probing. Interviews were semi-structured to allow interviewers to follow up areas of interest as they arose. The topics for both routine and non-routine events were the following:

- What were the main goals and objectives in relation to inpatient diabetes?
- What challenges arose; how were these responded to and/or overcome?
- What bearing did previous experience/learning have on decision making?
- What courses of action were followed and why?
- What information sources were used when providing and monitoring care?
- What were the benefits and drawbacks of specialist teams?
- What were the anticipated needs for further support, for example, training and decision aids?

2.5 Data analysis

Data were processed and analyzed using QSR NVivo 9.0 data analysis software (e.g., Tagg and Crowley 2002), which allows for a single file to be created for all interviews to store data and link ideas as they develop. Analysis took place by way of two main procedures. First, codes were generated from initial readings. Sections of text were coded by independent researchers, and the coding framework was refined during discussions between researchers. The second stage of the analysis involved applying the framework to identify themes and interactions with a particular focus on complexity, coordination, gaps and discontinuities.

As this type of analysis is thematic rather than quantitative, the common practice of making repeated comparisons between the interpretations of different analysts was followed (Thorndike 1951). Final concepts were re-examined in light of coding agreements and disagreements to achieve interrater consensus (Davies et al. 2003), and the final codes were those that best discriminated between distinct ideas expressed by participants.

Finally, the study can be summarized as follows:

1. The setting was an acute hospital, and the system was defined as inpatient diabetes care, including a specialist team and non-specialist (ward based) staff
2. In-depth data about the operation of the work system were elicited via CDM interviews ($n = 32$; quota sample) adapted to probe both critical and non-critical events
3. Rigorous analysis of texts using a framework derived from the principles of resilience engineering
4. Examination of sources of complexity, adaptation, coordination, gaps in care and how they are bridged, and unintended consequences of attempts to bridge gaps
5. Identification of potential interventions to bridge gaps in care.

3 Results

3.1 Model of the work system

Rigorous analysis of the transcripts resulted in a model of the work system which represents the way staff (diabetic specialists and acute medicine non-specialists) describe their system of work. In effect this is a concept map showing how the participants view their work system (Novak 1977; Novak and Canas 2006).

The aim was to provide a model of how the decision system under investigation operates as a basis for (a) further thematic analysis of adaptation, coordination and gaps in care and (b) designing interventions to improve care. The model is shown in Fig. 1.

Key features of the work system model in Fig. 1, induced from the critical decision interviews, were the following:

- Cases can be complex requiring synthesis of information to derive clinical objectives and anticipate potential problems
- In making decisions about care plans and treatment, clinicians balance clinical aims and organizational factors that may either enhance or lead to gaps in delivery of care (staffing, equipment and procedures)
- Clinical outcomes emerge from interactions between patient and organizational factors, mediated by coordinated care plans and processes
- Monitoring and feedback may lead to revised decisions and/or clinical aims as well as organizational learning/changes.

The model presented in Fig. 1 represents a high-level overview of how decision making occurs in this work system. Further thematic analysis was then performed using principles of resilience engineering (Hollnagel 2009) to examine the following: challenges and sources of complexity in this domain; how care is coordinated by multiple actors; gaps and discontinuities in care; how practitioners attempt to bridge these gaps; and scope for interventions to support practitioners. These are discussed in the following sections.

3.2 Sources of complexity

The main challenge in maintaining good-quality care for diabetes patients arises from the clinical complexity of the cases and the organizational context. As well as presentation with acute diabetic ketoacidosis or related conditions (e.g., a necrotic foot ulcer) patients may present with a range of medical conditions, impairments or disabilities ([…]*they do come with their own medical requirements as well, problems with their eyes, kidneys, pretty much*

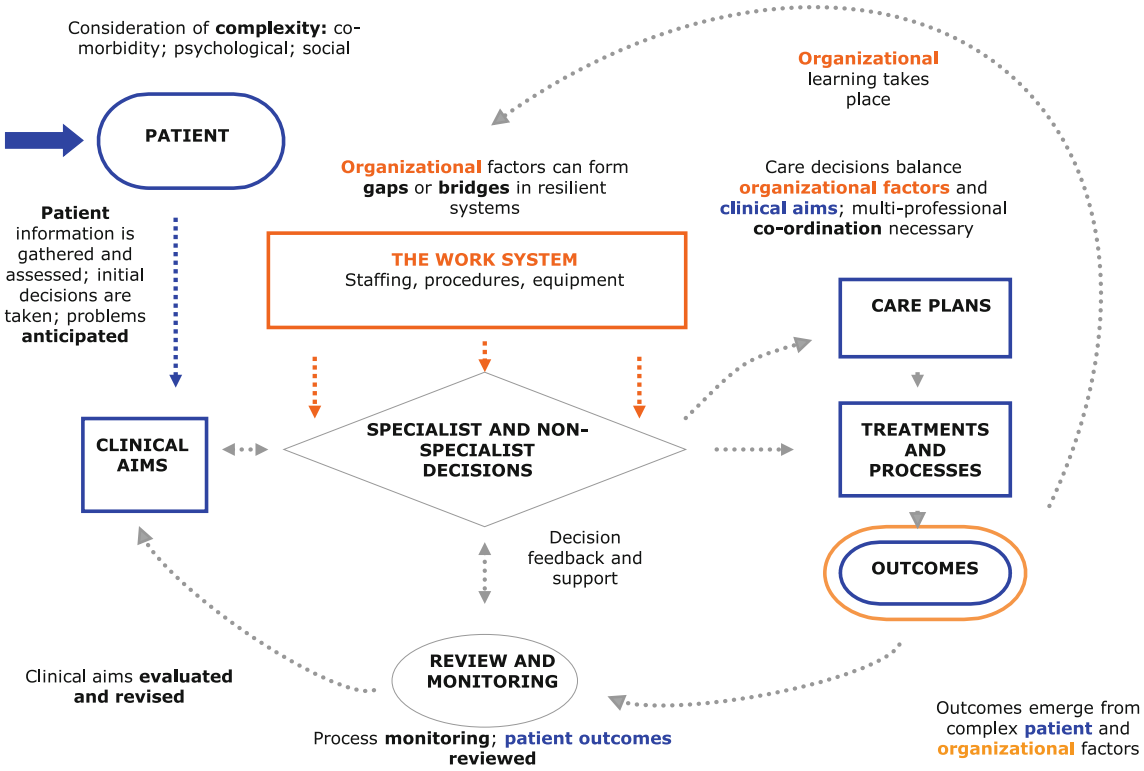

Fig. 1 Model of the inpatient diabetes care work system

anything; Junior doctor) as well as psychological and/or substance use issues.

There may be further social circumstances to take into account in care plans including home support or otherwise (e.g., homelessness); lifestyle, diet and nutrition; and language difficulties. Where such clinical complexity is encountered, specialist involvement is more likely: *[…] patients that […] have complex conditions which cause their diabetes to be quite challenging. They're generally the patients that I see* […] [Diabetes Specialist Nurse].

The organizational context was described in detail by many participants. The acute environment is highly time-driven with organizational imperatives around assessment and discharge that hold for both nurses and doctors*: I think the pressure is on to make sure that things are kept moving and investigations are done quickly […] so that their whole process is run through the whole patient journey […]* [Specialty Registrar, acute medicine].

Assessing patients, planning care, carrying out treatment and responding to problems require allocating and managing a finite set of organizational resources including equipment; staff time and availability; physical space; and procedures and documents. The work system can frequently impinge on simple tasks: *[…] there wasn't a room in clinic to see him in. We had nowhere to go and I had to fight for space […] so it was all a bit fraught, a bit tense* [Diabetes Specialist Nurse].

Funding pressure was perceived as constraining learning and putting a strain on the specialist nurse resource: *we just can't send* [staff on diabetes courses] *because of the funding. Then you're relying on the nurse specialists to do more formal training on the ward […] there was a diabetes programme that ran but it kind of fizzled out* [Ward manager].

3.3 Co-ordination of care

The delivery of appropriate care relies on the coordination of staff knowledge and skills. Care is provided by a multilayered clinical team including consultants, registrars, diabetes specialist nurses and doctors, healthcare assistants and ward staff with different priorities, skills and knowledge. The data illuminated key differences between staff groups in how they conceptualize care, their skills and roles and their decision-making processes.

Ward staff follow treatment protocols (e.g., insulin sliding scales) and take careful, routine observations on which decisions about care are based. They contribute to good outcomes mainly by procedural or rule-based decisions based on routine observation: *You know these scales […] we have to do it hourly. […] When you do the blood sugars, if it gets to a certain amount […] the form says you have to do the urine at the same time […]* [Healthcare Assistant]. This example shows a typically

process-orientated approach with a fairly narrow focus (i.e., blood sugar management). There is limited freedom for action inherent in such descriptions of critical decisions required and taken.

In contrast, specialists take a holistic view of the patient and are less concerned with healthcare functions, tasks and processes. They make higher-level decisions taking into account the clinical complexity of each case: *Is this patient okay? Will this patient do well […] checking his blood sugars, giving his insulin? Is he going to cope at home? […] Can we keep the patient another day? […] go through what we did yesterday […] is there anything else? […] Have I left anything out? Is there anything that you want to ask me?* [Diabetes Specialist Nurse].

DSNs and specialist doctors make knowledge-based decisions rather than simply following protocol: *So it's a bit like a jigsaw puzzle and how you put it, all the pieces together* [Diabetes Specialist Nurse].

The specialist team also coordinates the multidisciplinary response to complex cases: *surgeons, vascular, orthopaedics are involved, other specialties like the renal, haematology […] it's absolutely multi-disciplinary, […] it involves the diabetic foot practitioner when they go home, […] and all this has to be arranged. The GP has to know about what has happened* [Junior doctor].

Where patient knowledge or compliance is an issue, specialists also provide patient education with a view to empowering patients to self-manage their condition. This facilitates discharge and prevents readmissions: *[…] we are looking at discharging them […] Patient teaching—how to give insulin when they're at home, things like that […] So they give a lot of input with our patients, especially newly diagnosed* [Staff Nurse]; *hopefully that means that they're in charge of their condition rather than us spoon feeding everything* [Consultant, acute medicine].

Diabetes specialist nurses also provide support for diabetes treatment titration in routine cases. They will collaborate with senior specialist team members and share information and decisions, but in this healthcare setting, they are unable to prescribe medications (unlike both non-specialist and specialist diabetes doctors), which can delay treatment: *I discussed it with, obviously one of my medical colleagues and that was difficult because everyone was busy in clinic […] trying to find a doctor to discuss the patient with. I'm a nurse prescriber but I can't prescribe in [this hospital] […] that delayed the whole process.* [Diabetes Specialist Nurse].

Senior 'non-specialists' (junior doctors, registrars and consultants) also have to address clinical complexity given the nature of the acute medical environment in which they work. They may not have a diabetes overview and will refer to specialist diabetes staff, but will usually be involved in case management and long-term review. Junior doctors in particular alternate between higher-level knowledge-based decisions and checklist/protocol-driven ones. They may have varying experience, authority levels and situational awareness of diabetes inpatient management.

In summary, the main specialist contribution to ongoing management of diabetes patients is their extensive knowledge and experience of previous cases (see Sect. 4). Information to be assessed may be clinical/physical, psychological and/or social. This provides decision support for non-specialist staff and help and advice for patients and carers. The specialist team is seen as beneficial in terms of better knowledge for control of diabetes in general and specifically in reducing complications, minimizing risk of infection, facilitating a shorter inpatient stay and minimizing risks of readmission.

3.4 Gaps and discontinuities

The coordination of the diverse clinical workforce is a key task for maintaining resilience, and where coordination is not successful, gaps in the delivery of care and threats to safety emerge. Participants identified a number of gaps in the continuity of care that threatened the quality of care. For example, referral may be delayed where diabetes is not the primary diagnosis: *[…] what we found out is that people are very good at making referrals for people who are admitted with diabetes; […] but those who don't have complications and they come in for something else […] the sugars are through the roof […] they don't call the diabetes team so quickly* [Diabetes Specialist Nurse]. Clinical inertia resulted in treatments not being titrated (or changed if ineffective) or patients not being recognized by non-specialists as having a high need for diabetes specialist intervention.

The structure and organization of the hospital can contribute to gaps in care. For example, staff education can be compromised due to the difficulty of gathering groups of ward nurses together: *Because you wouldn't get all the ward nurses at the same time, no, no, annual leaves, days off, shifts* [Diabetes Specialist Nurse]. Nutrition is also a vital area of diabetes management and treatment where clinical aims may be compromised by an inability to manage the operations of the hospital, meaning that close integration of insulin treatment regimes and meals is not always achieved: *they've had such and such a food and they don't get their insulin an hour, 2 hours till after they've eaten […]* [Diabetes Specialist Nurse].

Resource limitations and staff scheduling mean that specialists are not always available (e.g., at weekends and out-of-hours) leaving the provision of safe care dependent on the skills and knowledge of ward staff: *[…] there is very little sort of available out of hours diabetic specialist*

support […] covering the acute medicine inpatients, you know at weekends and certainly out of hours there wouldn't be anybody available […] [Clinical Lead, acute medicine].

Information gaps were also reported requiring repeated attempts to communicate with other professionals: *After I'd seen him I rang the GP just to find out more information, […] their computer system [appeared] to be a bit confused about what insulin regime he was on, what they had on their system was different from what he had described to me […] then last week I phoned the surgery again […] and they hadn't been informed […] So one of the challenges, the clinical challenges was that there was no history to go on of how he responded to the medication […]* [Diabetes Registrar].

3.5 Bridging gaps

The diabetes specialist team bridges gaps in expertise and knowledge in several ways. They respond reactively to referrals from non-specialist staff across the hospital when observations suggest treatment may need to be altered or acute complications occur. Treatment is then managed by ward staff acting on the direct advice of specialists: *the doctors, on the ward, if they are not confident to adjust, would always bleep […] the diabetes registrar […] to come in, have a look again, if you think the sugars are still not settling down* [Diabetes Specialist Nurse].

Second, specialists proactively identify cases requiring their expertise by conducting systematic and scheduled reviews ('sweeps') of the admission unit where the aim is to pick up potentially difficult cases: *[…] they review everybody, the people they feel are complex they will refer to the registrar, […] occasionally the diabetic consultants come to the ward to see the more complex patients and then obviously give advice or do things* [Ward Manager].

These 'sweeps,' conducted daily, are resource intensive but provide opportunities to intervene early before problems escalate and to educate ward staff about patient management: *They come in everyday. […] the turnover is very high and we have all sorts of patients coming in. […] So they go through the handover sheets and they just identify those who are diabetic patients […] and if there is anyone challenging […] then they can refer to their registrar […] every day we have a diabetic nurse visiting the ward.* [Senior Nurse].

Finally, specialists also provide education, advice and support to patients: *Yes, a lot of what I do is type 1 education and insulin pumps […] so it's structured education for patients with type 1 diabetes* [Diabetes Specialist Nurse].

As discussed above, coordination of multidisciplinary working is a major role for diabetes specialists and helps to address communication gaps between clinical partners and between patients and staff: *we already are a multi-disciplinary team [we have] dedicated psychiatrist […] clinical psychologist and specialist nurses […] there at the outset. One of the things that makes it more challenging is continuity of care because inevitably as an in-patient there's going to be multiple different people involved in the management with shift cover and making sure that people understand the issues and […] to make sure there is a clear message where everybody […] understands the plan, this is a very important aspect of treating them, it's one of the barriers. The other barriers are to make sure that the ward staff understand the issues […] having staff understanding behaviour issues in patients and how to handle them.* [Consultant diabetes].

3.6 Unintended consequences

The introduction of the specialist diabetes team has had unexpected and unintended consequences. Many participants reported the erosion of ward staff skills as a particular problem. *The potential downside of having a good specialist team is that you actually de-skill the wards and there's a degree of learned helplessness in some areas where there's a lot of diabetes input where the ward staff do not engage because they leave it to the diabetes team and that is a negative thing in itself* [Consultant, diabetes].

Learning may be inhibited by non-specialists because they can call for help; thus, they will begin to rely on help even when cases are not particularly complex or challenging, thus overburdening specialists: *they now rely on us to go and review their patients and I think we may have taken away that learning curve from them unfortunately; One of the potential drawbacks is that… well you could suggest that there be a de-skilling of others to manage inpatient diabetes […]* [Diabetes Specialist Nurse].

Skill erosion leads to reliance on protocols and procedures, and there was concern that delays in seeking help could occur in complex cases where staff should recognize the need for prompt action.

3.7 Scope for helping practitioners bridge gaps

Participants identified potential interventions to bridge gaps in knowledge and expertise. Many recommendations centered on the need to make use of available information and to have good feedback and review mechanisms, for example, by keeping good computer records; noting quality markers such as time from referral to being seen by a specialist; designing assessment measures to ensure diabetes competence; making better use of incident reporting data; or understanding diabetes pathways better through peer protocols.

Specialists outlined a need to develop decision support tools in areas such as electronic prescribing to encourage treatment change and prevent clinical inertia; improve communication on follow-up arrangements, for example, clinic appointments; and assign complex cases with a primary diagnosis of diabetes to the specialist diabetes ward as quickly as possible to allow for earlier, more intense specialist input.

Updating knowledge was seen as vital, for example, through using link nurses or through ongoing discussion and study days or formal training courses: *[…] it would be nice […] if there was more of a formal training programme so more of the junior staff nurses, the newly qualified nurses get the same education and support […] even just like a study day to give them more information about what's going on* [Ward manager].

Information technology was also inadequate. Although Electronic Patient Records (EPRs) were used in the hospital, this did not entirely remove the need to scan paper documents. One specialist argued for e-guides ('apps') for diabetes: *an online algorithm that you could use and you can put in their total daily dose, work out what the blood sugars are doing and the computer could do it for you, you know, like an 'app' or something like that, and that would be the way forward because then it's your clinical decision-making plus you'll have useful computer guidance to help you in your dosages […]* [Specialty Registrar, diabetes].

Ward staff recommendations for continued improvement included changing non-specialist attitudes to diabetes care by having dedicated specialists affiliated to each ward; individual non-specialists choosing to be 'champions' in their local clinical areas to effect culture change; and more regular training for ward staff from specialist nurses particularly on insulin types and regimes.

4 Discussion and conclusions

Despite the fact that studies have identified problems in delivering diabetes inpatient care, the key concepts, processes and interactions in providing care in the complex hospital environment have not been fully explored. In this study of the technical work of caring for diabetic inpatients, we investigated in depth how diabetes care is organized and delivered and how knowledge and skills are distributed across multidisciplinary team members. In the following sections we discuss how resilience is created, maintained and breaks down in the complex domain of inpatient diabetes and consider the implications for ongoing quality improvement.

Diabetes care is delivered through a complex multilayered system where expertise and decision making is distributed across different groups of professionals who have different roles, different clinical aims and goals, and who think about the work system in different ways.

Ward nurses describe their work in terms of rule-based decisions (Rasmussen 1983) and reliance on protocols. Thus, they work on a fairly reactive basis, monitoring signs and adjusting according to convention. Although there are individual differences between nurses, in general their ability to reason from first principles about glucose metabolism in individual patients and extrapolate to diagnose problems and needs is limited.

The challenges they face in caring for diabetic patients are similar to those faced by patients self-managing their diabetes, which has been described by others as a complex cognitive control task (Klein and Meininger 2004; Klein and Lippa 2012). It requires deep understanding of the multiple factors that can affect blood sugar levels and an ability to anticipate the trajectory of the levels and intervene in time if they will be, or are, out of range. This task is complicated by the need to manage the condition for which the patient was hospitalized, and follow protocols and orders for diabetes care.

Diabetes specialist nurses and consultants both provide case assessments and overviews and describe their work as solving problems and making knowledge-based decisions (Wirstad 1988). Thus, they coordinate the care of patients by bridging knowledge gaps between professionals and anticipating difficulties based on previous experience. Wilson and Holt (2001) outline how holistic interpretation of patient histories, taking into account the unpredictability and 'subtle emergent forces' of physiological processes is inevitable in complex clinical care contexts.

This empirically observed difference between staff groups is typical of reported expert/novice distinctions (Kushniruk 2001) and has been discussed in the context of the study of technical work in other domains. For example, Barley and Orr (1997) have discussed how growing specialization within professions has increased the need for collaboration between specialists and less well-trained generalists and technicians.

In practice, good care depends on coordination vertically through the hierarchy of the organization, laterally between domains and specialties and longitudinally, to ensure that knowledge about the patient state is continually updated and monitored (Nyssen 2007). In this study, the diabetes specialist team operated as a central coordination mechanism, harnessing and disseminating information and knowledge, and monitoring and anticipating problems.

The key challenge within this system is to maintain resilience by ensuring that potential gaps in knowledge and expertise are bridged. This implies that non-specialists must have sufficient awareness and knowledge to identify when the limits of their expertise have been reached and

when specialist input is required. The specialists need to have enough resources to meet these needs. The results of this study showed that this can be problematic, with ward staff sometimes over-referring to specialists, taxing resources and depriving them of the opportunity to hone their skills and knowledge, and at other times missing cues that expert input is required until a problem has developed into something more serious.

The diabetes specialists increase the adaptive capacity, and therefore the resilience of the care system by enabling appropriate and timely responses to challenging cases. Adaptive capacity is taxed by patients with multiple needs and complicating factors that make stabilizing their blood sugar levels difficult. Experts with deep knowledge and understanding contribute to resilience by picking up early signs of problems, anticipating developments and mobilizing resources to avert further deterioration (Nemeth 2008). The need for coordination among multiple professional groups is in itself a source of complexity requiring explicit coordination mechanisms (Nyssen 2007).

The main threat to resilience we have reported is skill erosion whereby ward staff come to rely on specialists for overall management of diabetes, even in straightforward cases, and lose their skills, knowledge and decision-making capacity. Resource limitations and staff scheduling mean that specialists are not always available, threatening resilience and the ability of the system to provide safe care at all times. The planned *link nurse* role (McKeeney 2003), in which ward nurses acquire deeper diabetes knowledge and act as a link between the specialist team and the ward staff, is a strategy intended to overcome this potential gap in safe systems of care.

This study provides detailed evidence on which to base ongoing quality improvement efforts. Mapping the technical work system and identifying gaps and bridges has been fruitful. Strategies to embed knowledge in the system and bridge gaps between different groups of professionals are necessary and will evolve as demands and available resources change. The results indicate there is scope for decision support and protocols in areas such as referring to specialists, detecting and managing problems in blood glucose levels, and patient self-management including further work in supporting patients in the less structured outpatient environment.

However, no one model of decision support will be applicable across the system; Perry and Wears (2009) describe difficulties in application of strict procedures for blood sugar monitoring and control. Formal methods for supporting decisions tend to be applied to simple models and to make assumptions about logical choices, which is perhaps why their application in health care has been problematic (Bokenholt and Weber 1992; Poses et al. 1995).

4.1 Conclusions and recommendations

In conclusion, the specialist team can increase resilience in the system by complementing ward level care for diabetes, providing there are no unintended consequences of specialist input. The specialist team serves to coordinate decision making around the various patient considerations, plans and processes outlined in Fig. 1. This opens lines of communication and feedback/monitoring, detects problems early, manages hazards and reduces future risk by addressing organizational, educational and multidisciplinary support issues. It is therefore an important element in a resilient system. Iedema (2009) states that 'resilience relies on a team's distributed cognition […]; that is, the team's active sharing and updating of their knowledge, enabling risks to be collectively and progressively monitored […]' (p. 1702, citing Hutchins and Klausen 1998; Boreham et al. 2000).

Finally, we have reported a number of recommendations which map onto our model of the work system in Fig. 1. Ward staff need education and training to support treatment/process and critical decisions (Cook et al. 2007); organizational systems need to be supportive; and specialists need to be involved early to support good care planning and coordination. In reality, ongoing work is likely to involve multitargeted approaches which address most or all of these issues as 'attempts to improve long-term safety in complex systems by analyzing and changing individual components have often proven to be unsuccessful over the long-term' (Leveson 2002, p. 49).

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