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Detailed analysis of 'work as imagined' in the use of intravenous insulin infusions in a hospital: a hierarchical task analysis

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ABSTRACT

Objective Variable rate intravenous insulin infusions (VRIII) is a high-risk medication that has a potential to cause significant patient harm if used in error. Complex preparation of VRIII in clinical areas and the need for frequent monitoring and adjustment increase the complexity of using VRIII. An emerging approach, called Resilient Healthcare, proposes understanding complexity of work by exploring how work is assumed to be done and compare it with everyday work. This study aimed to explore how VRIII is perceived to be used by healthcare practitioners, focusing on one aspect of Resilient Healthcare: understanding how work is assumed to be done, using a method called hierarchical task analysis (HTA).

Design A qualitative study using document analysis and focus groups.

Setting A vascular surgery unit in an acute National Health Service teaching hospital in the UK.

Participants Stakeholders/users in different professional roles involved in the process of using VRIII.

Results The HTA showed the complexity of using VRIII and highlighted more than 115 steps required to treat elevated blood glucose. The process of producing hospital-specific guidelines was iterative. Careful consideration was taken to coordinate the development and implementation of guidelines. Documents provided detailed clinical instructions related to the use of VRIII but practitioners selectively used them, often in deference to senior colleagues. Intentional adaptations, for example, proactively asking for a VRIII prescription occurred and were acknowledged as part of providing individualised patient care.

Conclusion Using VRIII to treat elevated blood glucose is a complex but necessary process mediated by a range of factors such as organisational influences. Adaptive strategies to mitigate errors were common and future research can build on insights from this study to develop a broader understanding of how VRIII is used and to understand how adaptations are made in relation to the use of VRIII.

Strengths and limitations of this study

- ► To the best of our knowledge, this is the first study to explore Work As Imagined in relation to the use of variable rate intravenous insulin infusions (VRIII).
- ► Multiple data sources, that is, document analysis and focus group meetings were used to understand how work is imagined while using VRIII.
- ► This is the first study that used hierarchical task analysis to illustrate the tasks that were expected to be done while using VRIII.
- ► The low number of focus groups participants might not represent the perspectives of all the staff who might have given different views on the tasks of using VRIII.
- ► Discussions with focus groups participants about the guidelines that were implemented a few years ago may have been a potential source of recall bias.

INTRODUCTION

Controlling blood glucose (BG) in hospitalised patients is very important for optimal patient outcomes. Globally, variable rate intravenous insulin infusions (VRIII) is considered the treatment of choice to achieve optimal BG levels in hospital inpatients who are not eatingand those with some acute illnesses, for example, sepsis.[1 2] Studies reported in the scientific literature describe benefits from using VRIII to control elevated BG levels, including reduced mortality, less time spent in hospital and improved wound healing.[3 4] However, if used incorrectly, it can result in patient harm from hypoglycaemia, rebound hyperglycaemia and diabetic ketoacidosis.[5]

Complex systems and clinical complexity

Contemporary healthcare systems have been described as complex adaptive system (CAS) where components in a system act in a dynamic network, constantly react in unpredictable and non-linear ways resulting in the emergence of outcomes [6 7] The level of complexity in healthcare systems has increased exponentially with each new diagnostic, therapeutic and technological discovery.[8] The use

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of VRIII is also complex and can result in unpredictable outcomes. A range of factors such as medication-related factors, for example, the limited evidence for a threshold for starting VRIII[1]; patient-related factors, for example, associated comorbidities[9]; provider-related factors, for example, fear of hypoglycaemia[10]; task-related factors, for example, frequent (hourly) BG monitoring[1] and hospital-related factors, for example, complex and variable guidelines and staff shortages,[9] contribute and influence the clinical complexity of using VRIII.

Safety in the use of VRIII

A variety of national and international interventions and initiatives have been reported to improve the safety of using VRIII, including using advanced glucose monitoring technology that measures BG continuously and alerts for hypoglycaemia or hyperglycaemia episodes,[11] specialist diabetes nurses,[12] the Think Glucose campaign,[13] double checking, standardisation of VRIII guidelines, providing ready-to-administer injectable medications and extra education and training for healthcare staff.[14] In the UK, the Joint British Diabetes Societies for Inpatient Care (JBDS-IP) was established in 2008 to improve inpatient diabetes care through standard setting and clinical guidelines development.[15] A recent audit assessed the breadth of the JBDS-IP guidelines' adoption in the UK.[15] It was found that 88% of the surveyed hospitals adopted the VRIII guidelines for medical inpatients, and around 58% of healthcare practitioners in these hospitals felt that the guidelines' adoption had improved clinical outcomes and patient safety.[15] Despite the high adoption of the VRIII guidelines and other safety initiatives, the 2018 National Diabetes Inpatient Audit (NaDIA) revealed that the percentage of inappropriate use and duration of use of VRIII have not changed significantly since 2011 and that errors still persist.[5] A possible explanation for this is that some traditional safety approaches, for example, standardised practice do not always take into account the constantly changing and complex nature of healthcare systems. Greenhalgh and Papoutsi illustrated the need to design and implement research methods that appreciate dynamic interactions and emergence in CASs, and understand from different perspectives how the whole system works.[16] Recent safety literature shows a growing interest in what is called Safety-II, which advocates investigating how things go right instead of only focusing on how a particular failure had happened (Safety-I). Resilient Healthcare (RHC) acknowledges that variability in performance is inevitable. It does not argue for a total replacement of Safety-I with Safety-II, rather proposes that it is necessary to focus on how everyday work can be performed successfully (what goes right) as well as how work has failed (what can go wrong) in order to improve safety.[17 18] Various data collection methodshave been used to study RHC, including using the four capabilities of RHC, that is, respond, monitor, anticipate and learn, investigating performance variability and Work As Done (WAD) and integrating RHC with other safety paradigms.[17]

Modelling 'work as imagined'

Work is defined as a physical or cognitive effort/activity directed toward achieving a specific goal or task.[19] This study is part of a wider project for which there is a published protocol.[20] There have been many research studies discussing the quality of different process modelling approaches.[21 22] Although a sequential flow diagram is considered the most commonly used process mapping approach in healthcare, there have been precedents for using hierarchical task analysis (HTA) for analysing and mapping complex healthcare systems.[23 24] An HTA is known as a prerequisite task analysis that is developed from general to specific. HTA answers what must the user know or do to achieve the goal.[25] However, the sequential process map is developed step by step and linearly to answer what are the methods that the user must go through in order to complete a specific activity.[26] Colligan *et al* conducted a study to examine the effect of a sequential flow diagram and HTA on the healthcare practitioner's judgement. The results of that study found that HTA was easier to produce graphically and review as the mapping progressed, flexible in representing specific goals which did not correspond to specific acts or times, and encompassing unpredictability of healthcare activities with a focus on goal rather than the precise method. HTA is one of the most commonly used task analysis techniques[27] to understand and analyse the complexity of the work. In this study, HTA was used to investigate work is imagined (WAI) in the use of VRIII from different perspectives. HTA was developed based on the theory of performance and has been used to describe system dynamics and human-system interfaces.[28] HTA is a flexible and generic tool and has been applied in different domains[25 27] such as in the process control and power generation industries and recently in medication administration and management.[29 30] The use of VRIII is driven by the need to identify and achieve the goal of patient care despite the variability in patients, availability of staff and the demands on the system.

Study aim

In this study, we aimed to systematically explore WAI when using VRIII from multiple perspectives. The findings of this study may be the first step for healthcare practitioners and policy makers to create robust understanding of the reality of WAI to improve patient safety in relation to the use of VRIII.

METHODS

Study design

This research drew on the constructivism paradigm, which emphasises the importance of the context in the process of knowledge construction and accumulation.[31] This

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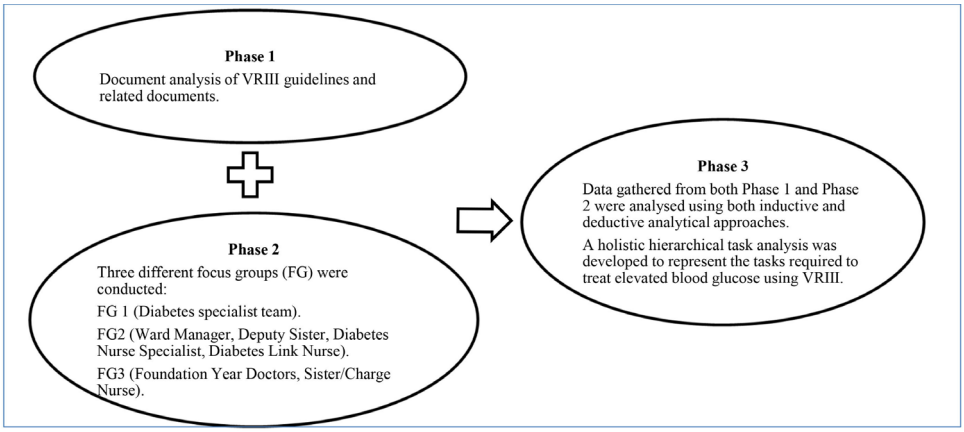

Figure 1 Diagram summarising the three different phases of the study. VRIII, variable rate intravenous insulin infusions.

paradigm shaped our view of what type of knowledge about WAI would be of value.[32] For the purpose of this study, a descriptive, systematic approach was applied to establish empirical data with a view to exploring how WAI in the use of VRIII.[33] The researchers interpreted and analysed data from documents and focus groups (FGs) drawing on their own experiences, in order to construct a deep understanding of WAI as it is described in the guidelines and how practitioners think they use the VRIII guidelines. This study was conducted in three phases: (1) document analysis; (2) FG discussions; (3) the development of the HTA by merging of the data from both sources. Figure 1 illustrates the study phases to represent WAI in the use of VRIII.

Study setting

The study was conducted at the vascular surgery unit of an acute National Health Service (NHS) teaching hospital in the UK.

Phase 1: document analysis

All current hospital-specific documents that described key tasks related to the use of VRIII to treat elevated BG in adult in-patients, such as indications for use, prescribing, administration, monitoring, adjusting infusion rates and transition to other medication, and were readily available on the hospital's intranet (see box 1), were included. These documents were used to develop understanding and discover insights relevant to what is expected when using VRIII.

Box 1 Documents related to the use of variable rate intravenous insulin infusions (VRIII)

1. Guidelines for VRIII in adults.
2. Guidelines for management of diabetic ketoacidosis in adults.
3. Guidelines for management of hyperosmolar hyperglycaemic state in adults.
4. Managing diabetes in adult inpatients before, during and after operations and procedures.
5. The management of hypoglycaemia in adult inpatients.
6. Hand hygiene policy.
7. Aseptic non-touch technique (peripheral and central access intravenous therapy).
8. Recording Line Insertion and Visual Infusion Phlebitis Score.
9. Patient identification policy.
10. Visual Infusion Phlebitis Score.
11. Procedure for preparing and administering injectable medicines.

Phase 2: FGs

Sample

A purposive sample of stakeholders/users with different key responsibilities (guidelines developers, managers and healthcare practitioners) involved in treating elevated BG using VRIII were recruited. There is no definite sample size for qualitative research. It depends on a range of factors including the underpinning methodology, the scope of the research question, and the resources available.[34] Summary information about FG participants' characteristics can be found in Table 1.

Recruitment

Participant recruitment for the three FGs was undertaken over 6 months (December 2018–May 2019). Specifically, the hospital collaborator sent an email invitation letter and participant information sheet outlining the purpose of the study to potential participants for FGs 1 and 2. The clinical and managerial leads sent an email invitation letter and participant information sheet for FG3. The researcher attended two ward meetings to meet as many healthcare practitioners as possible to explain the aim and methods of the study. Interested participants contacted the researcher directly via email. On the day of the FG and prior to the session, the researcher explained the study to the participants again, allowed time for any other questions they may have about the study and took informed consent.

Data collection

The three FG meetings took place in a quiet meeting room at the vascular surgery unit and lasted approximately 30–45 min, each. The research team, including the hospital collaborator, developed the FG topic guide (see online supplemental file 1). The topic guide was informed by the results of the document analysis. A topic guide included open-ended questions, and a case scenario

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Table 1 Characteristics of focus groups (FG) participants

	FG1 guidelines developers	FG2 managers	FG3 healthcare practitioners
Sample	Diabetes consultants, pharmacist and diabetes specialist nurses.	Nurses (ward manager, deputy sister, diabetes nurse specialist and diabetes link nurse that is, registered nurse with an expressed interest in diabetes and a formal link to diabetes specialist team).	Foundation year doctors (medical graduates entering the medical workforce as 'junior doctors' on a 2-year work-based training programme) and Nurses (Sister/ Charge Nurse).
Role	Develop and disseminate guidelines for the use of IV insulin infusions.	Implement guidelines, allocate resourcesand staff training. Diabetes Link Nurse acts as a conduit between front line practitioners and the inpatient diabetes specialist team.	Work at the vascular surgery unit using intravenous insulin infusions and do not have a management role.
No of potential participants	4	10	20
No of recruited participants (%)	4 (100)	3 (30)	4 (20)

of treating elevated BG was used in all FG meetings to discuss the treatment plan based on their understanding of the VRIII guidelines used in their hospital. MHI (PhD candidate, pharmacist) moderated all the FG meetings. All meetings were audiorecorded, and the recordings transcribed verbatim.

Phase 3: data analysis

Data gathered from both documents and FG meetings were analysed using both inductive and deductive analytical approaches. The analysis began by analysing documents deductively, codes were determined based on the literature to provide details on the key tasks in the process of treating elevated BG using VRIII. Coding for the documents was conducted by a single researcher (MHI) with the aid of NVivo V.12, a qualitative data management software. Initial codes were then discussed within the research team (MHI, RL and KR) and mutually refined until they reached consensus.

After the initial stage of document analysis was completed, FG transcripts were analysed using both inductive and deductive analytical approaches. To enhance credibility, three of the authors participated in analysing the transcripts. MHI, RL and KR independently coded the transcripts. The three researchers discussed their codes until they reached consensus. Then codes from documents and FGs were constructed into candidate categories. For example, initial codes relating to preparing guideline were identified as 'best practice' (MHI), 'consensus, no robust evidence' (KR), and 'contextualise the national guidelines' (RL). Working together, MHI, RL and KR reinterpreted these codes into 'understand the context'. The categories from both document analysis and FGs were combined and refined according to the HTA objectives of identifying the overall goals, subgoals, subtasks, operations and analysing plans to explain how goals were obtained. HTA development comprised various steps, including defining task under analysis, determining the overall goal, determining task subgoals, breaking down subgoals until an appropriate operation was reached, and analysing plans to explain how goals were reached.[27] The HTA was constructed using the Microsoft Visio Professional 2019 software.

Developing the HTA was an iterative process. The researchers identified and agreed on the task under analysis and the overall goals. Three key subgoals from both the documents and FG transcripts were identified, reflecting important patterns in helping to answer the research question. Descriptions of subgoals were used to explain how goals were achieved. The draft HTA was validated with the wider research team and healthcare practitioners from the study hospital to establish the fit between the participants' views and the researchers' representation of the final HTA.[35]

Patient and public involvement

Patients and the public were not involved in the development of the research question, study design, recruitment and conduct of the study.

RESULTS

The final HTA diagram is presented in Figure 2. The overall HTA goal resulting from our analyses and interpretation of the hospital documents and FG participants' perspectives on how work was imagined in the use of VRIII, was to treat elevated BG in hospitalised patients using VRIII. Three key subgoals were identified: produce hospital-specific VRIII guidelines, implement the guidelines and use the guidelines. Each of these subgoals is presented individually, below. For clarity, representative quotations from participants are reported below; additional quotations can be found in online supplemental files 2 and 3.

Produce hospital-specific VRIII guidelines

A multidisciplinary team, composed of diabetes/acute medicine consultants, pharmacists and adult diabetes inpatient nurse specialists, was responsible for preparing hospital-specific VRIII guidelines. Producing guidelines took place in several iterative stages. 'Preparing a first draft' sub-goal was based on several resources such as the relevant JBDS-IP guidelines,[2] the NaDIA,[5] local incident reports, feedback,

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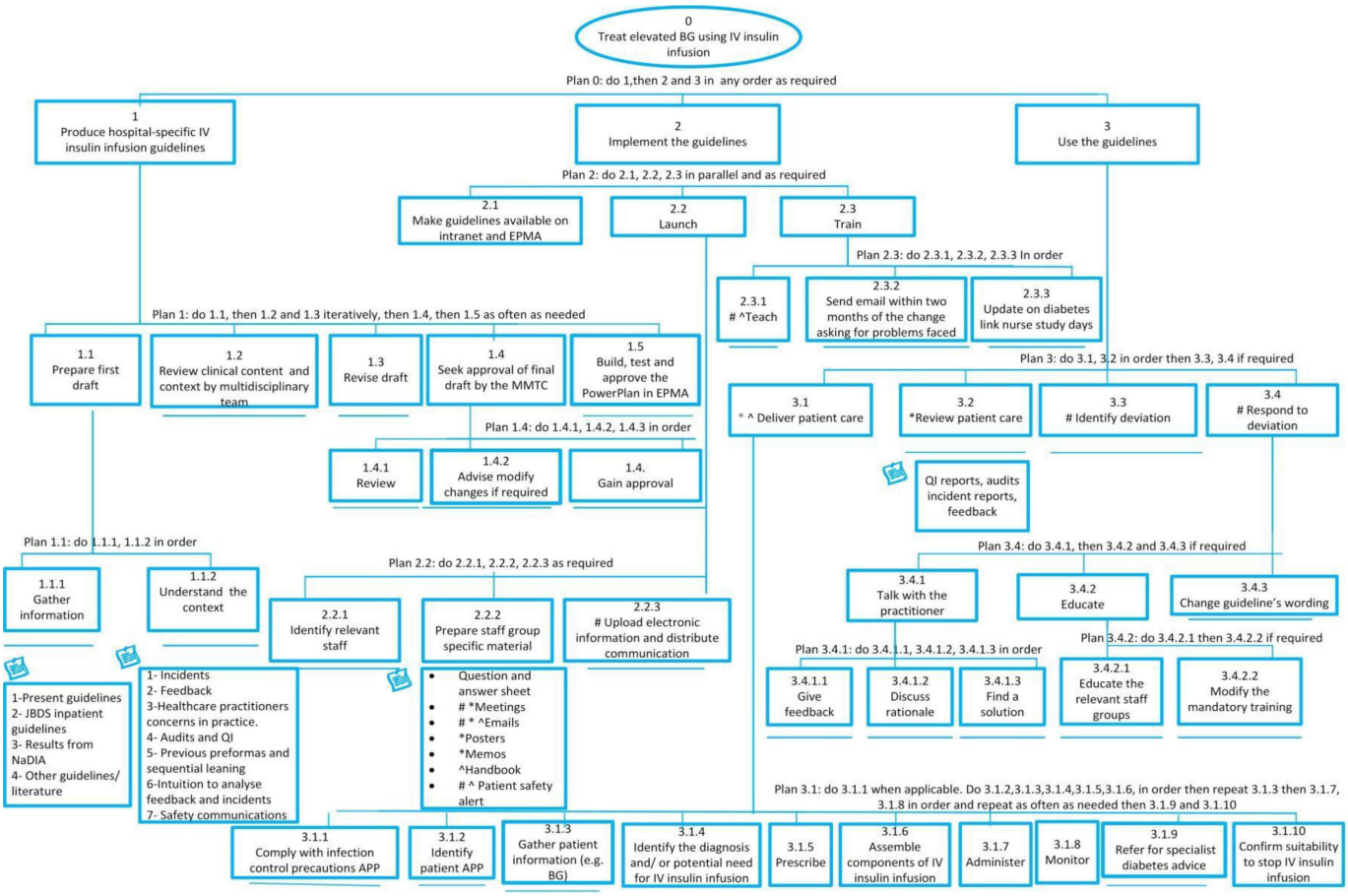

Figure 2 Hierarchical task analysis diagram of the process of treating elevated BG using VRIII. #FG1; *FG2; ^FG3. APP, as per policy; BG, blood glucose; EPMA, Electronic Prescribingand Medicines Administration; IV, intravenous; JBDS, Joint British Diabetes Societies; MMTC, Medicine Management Therapeutics Committee; NaDIA, National Diabetes Inpatient Audit; PowerPlan, Electronic prescribing and laboratory testbundle based on the local hospital guidelines; QI, Quality Improvement.

audits, quality improvement (QI) projects and intuition. FG1 data showed that all participants perceived 'reviewing the clinical content and context by multidisciplinary team' to be vital. Although the JBDS guidelines were used as the standard as they are considered best practice, it was clear that the hospital did not solely rely on these guidelines.

> 'That draft was based on loads of previous proformas and sequential learning and then when we done that we initially sent it round our Think Glucose…. So there is not necessarily a really a robust evidence base or, if you look at the JBDS… some of the ones where we could not just follow the template guidelines verbatim'. FG1

The hospital used different resources (eg, consulting the Think Glucose Group, which is a multidisciplinary group of healthcare professionals at the study hospital concerned with inpatient diabetes, an inpatient specialist nursing team who have extensive hands-on experience, and junior doctors) to adapt the national guidelines to make it relevant to their hospital. The guidelines were 'live' documents and underwent review, revision and then approved by a committee when required, in appropriate situations.

Implement the guidelines

Second, implement the guidelines started from a formal 'launch' of the electronic prescribing and laboratory test care bundle (PowerPlan). This progressed in parallel with widespread communication by 'making the guidelines available on the hospital intranet' and accessible to all practitioners, followed by 'training' relevant staff about the new guidelines. The importance of informing relevant staff was recognised where 'launch' consisted of several subgoals. The subgoal 'prepare staff group-specific material' was described by participants in all three FGs. This involved, for example, the adult diabetes inpatient nurse specialists providing a fact sheet to the link nurses, inviting them to explain the rationale of changes made to other nurses. Matrons also sent memos and emails to ward sisters requesting they inform all staff of the new changes.

> '… so he [link nurse] would go to the ward meeting and say this is happening…., the ward sister, may get a memo from her matron saying please can you get all your staff to revisit this policy? We'd also have ward-based training. So it isn't just one thing, it's different methods of reinforcing a change of practice or a change of policy'. FG2

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'Train staff how to use the guidelines' was another major subgoal in the task of implementing guidelines. To accomplish this subgoal:

- The guideline developers ensured that new junior doctors were taught how to prescribe VRIII. As the task of prescribing VRIII is complicated, the junior doctors were asked to use the PowerPlan, which was based on the local hospital guidelines. In addition, the doctors sometimes followed a hyperlink on the PowerPlan to access the full guidelines.
- Healthcare practitioners indicated that doctors were provided with a generic induction handbook not specific to VRIII as part of the training process when they joined the vascular surgery unit.
- Diabetes Link Nurses and ward sisters provided a brief (10 min) ward-based training covering three main points on a topic related to in-hospital diabetes management.
- The consultant body used medical grand round meetings to inform doctors about the latest changes and to discuss the rationale of new guidelines (eg, Hyperosmolar Hyperglycaemic State) and provide further information around them.
- Feedback was sought within 2 months of implementing the new guidelines, to identify any problems that had arisen, with responses being provided in separate communications.
- Update on Diabetes Link Nurse study days: the Diabetes Link Nurses were asked general questions and specifically probed about areas such as how often they managed to complete BG monitoring, where compliance might be difficult and to ascertain whether it was achievable, such as how often they managed to complete BG monitoring.

This way of training was used to gather as much feedback as possible in order to gain awareness of the problems practitioners faced and to devise solutions to them. It was clear from the three FGs that practitioners learnt by observing the practice of senior practitioners. The training and teaching relating to new practices happened through cascading—the 'chain of influence' technique[36] by which staff influenced one another in making decisions and resolving disagreements.

> '…I think we found out that we don't have the time or the staff to sit down for an hour and provide in-depth teaching to someone so [they've] started this what they call espresso teaching'. FG3

Use the guidelines

To accomplish this subgoal, almost all participants stated that staff are expected to follow the guidelines to 'deliver appropriate patient care'. As delivering patient care was perceived to have a direct consequence on patients' BG treatment, deliver patient care was further decomposed to ten sub-goals, using data from analysing the 11 documents related to the use of VRIII. The ten subgoals were 'complying with infection control precautions', 'identify patient', 'gather patient information', 'identify the diagnosis', 'prescribe', 'assemble components of VRIII', 'administer', 'monitor', 'refer for specialist diabetes advice' and 'confirm suitability to stop VRIII'. HTA diagrams for each sub-goal can be found in online supplemental file 4. The documents were clear and comprehensive and contained details about the aim, scope, responsibilities, training and monitoring compliance with precautions relating to specific tasks. There were, however, a lack of clarity in a couple of documents. In 'The Management of Hypoglycaemia in Adult Inpatients Guidelines', for example, when and at what rate to restart VRIII after managing hypoglycaemia was unclear. In 'Guidelines for VRIII in Adults', there was inconsistent guidance for example, it was stated to 'continue VRIII for one hour after the subcutaneous insulin (SC) has been administered to allow time for the insulin to be absorbed', while in the summary page it was recommended to 'stop intravenous insulin at time of first prescribed dose' of SC insulin. One of the guideline developers was contacted and this inconsistency was rectified. Participants in each FG discussed a variety of ways that are used to review patient care, such as QI projects, audits, comments and feedback from practitioners, and local incident reports.

Almost all participants agreed that the number of deviations from prescribed practice in the hospital was low. FG1 participants highlighted various situations in which healthcare practitioners might deviate, such as new doctors coming from a different Trust that have different guidelines, intentional deviations based on specialist advice related to a patient's case, difficulty with hourly monitoring for VRIII (resulting in monitoring being done every 2 hours instead of every hour), and the active choice to discontinue long-acting insulin when using VRIII. Unintentional deviation might occur because of challenges within the Electronic Prescribing and Medicines Administration (ePMA). For example, the FG1 participants highlighted that nurses were unclear about the order that prescribed intravenous fluids should be administered. As the ePMA system is not designed to show the order in which fluids are to be administered, FG1 participants emphasised the importance of a separate flow sheet to remind practitioners of the order in which to administer intravenous fluids. FG1 participants respond to deviations by having conversations and asking questions to identify the reasons behind the deviation, giving feedback, finding a compromise, providing immediate informal education, and finally changing the wording of guidelines if required. If deviations become a pattern, the Diabetes Specialist Team would conduct localised education in the ward and modify the content of mandatory training materials.

> 'So the insulin, you know the safe use of insulin is mandatory. Training has been modified based on incident and patterns that we see, so serious incidence and patterns that we see'. FG1

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DISCUSSION

The HTA showed the complexity of using VRIII by highlighting more than 115 steps required to achieve the key goal of treating elevated BG using VRIII. While HTA is typically applied to represent what people do,[29 37] HTA was used in this study to explore the process of treating elevated BG using VRIII. The HTA illustrated how the use of VRIII was expected to be done, and how practitioners use VRIII in a wider system in a hierarchy of goals. The study highlighted three key subgoals.

Produce hospital-specific VRIII guidelines

Producing hospital-specific VRIII guidelines was iterative and inclusive, with different specialities and committees included. Almost all participants described the documents as very practical, clear and user-friendly. The documents contained clear details about the aim, scope, responsibilities, training and monitoring compliance for specific tasks but the documents were written in a technical way that not every novice can understand unless they are very well experienced in hospital work generally and insulin use specifically. The comprehensive documentation could inadvertently result in a negative effect, as the large number of documents related to VRIII could confuse healthcare practitioners. Consistent with previous studies,[38 39] however, the importance of this comprehensiveness should not be underestimated; it serves as a backup and has a positive effect on patient safety by providing practitioners with all the information they need for using VRIII.

Implement the guidelines

The training and teaching around new changes to guidelines happens by cascading the 'chain of influence' technique, in which members influence one another in making decisions and resolving disagreements.[36] This way of training can be expressed as applying tacit knowledge, including skills, experiences, intuition and judgement, that is difficult to transfer to another person by means of writing it down or verbalising it.[40] While there was agreement that the hospital environment was very supportive in terms of training and education, there was a mix of proactive and reactive approaches to training new staff. If new staff did not know how to use VRIII, senior staff would train them. Senior staff would inform front-line practitioners about new changes or the training they needed with front-line practitioners often taking on a passive role. The current study showed that specific teaching sessions for junior doctors on using PowerPlan to prescribe VRIII were an essential part of the guidelines' implementation process to ensure patient safety while using VRIII. Lack of knowledge is one of the key barriers in delivering appropriate diabetes care.[41 42] An interventional controlled multicentre study was conducted to assess the impact of a strategy focused on educating healthcare practitioners. The strategy's impact on the quality of care was limited and there was no significant difference between controlled and interventional hospitals' education strategies for changing practitioners' behaviour.[43] Similarly, a systematic review conducted by Bain *et al* concerning educational interventions to improve prescribing performance, concluded that education was an important part of QI strategies in insulin prescribing; however, it was less effective when used in isolation.[44] It can thus be suggested that further work is needed that directly evaluate the effectiveness of the educational strategies used in the study hospital by exploring how challenging it is to achieve and sustain behaviour change.

Use the guidelines

The majority of the FG participants highlighted the importance of following the guidelines in order to deliver appropriate patient care while using VRIII. This finding is consistent with that of Sampson and Jones who concluded that the growing use of the JBPD-IP guidelines since 2011, has resulted in harm reduction related to the number of hypoglycaemic events and the unnecessary use of insulin infusions.[15] Many studies described various challenges with the use of VRIII such as the risk of hypoglycaemia, frequency of monitoring, insufficient nurse-to-patient ratio and confusion about the target BG level.[9 10 45] In contrast to previous studies, participants only mentioned two main challenges: sequence of administering intravenous fluids, and frequency of BG monitoring. On the one hand, the findings might not represent all the challenges healthcare practitioners face at hospital; on the other, the results are not necessarily transferable to all the vascular surgery unit healthcare practitioners and the whole Trust.

The general conclusion of earlier evaluations of ePMA systems in hospitals has been that they can improve quality, not least by reducing medication prescribing and administration errors.[46–48] However, one recent study found that although pharmacists valued a number of safety features associated with ePMA, they also perceived an overall increase in medication risk.[49] In a retrospective audit of VRIII comparing ePMA with bespoke paper proforma, there was improved completion of tasks where prompts were inbuilt but in other areas, completion rates were inconsistent.[50] This study found that nurses do not usually refer to the guidelines and doctors use the PowerPlan feature within the ePMA when prescribing. The fact that doctors usually rely on the ePMA might have mixed consequences. On one hand, it might save time in prescribing, as doctors are busy. On the other, if the ePMA system is not working for example, freezes, safety challenges might rise such as delaying patients receiving their medications and affecting the efficiency of ward rounds.

Prescribing intravenous fluids is a complex and an ever changing situation in which indication, fluid type, volume and rate depend on the pathophysiological changes that affect fluid balance in disease states.[51 52] In this study, prescribing intravenous fluids on the ePMA found another layer of complexity which was the lack of clarity about the order in which prescribed intravenous fluids should be administered. This result is in line with one study which found that some medications, such as insulin and intravenous fluids, were not safely prescribed using the system

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because their protocols did not fit easily into the structures embedded in the software.[53]

The availability of a fully staffed diabetes inpatient team is recommended to enhance patient safety and reduce insulin prescribing errors.[54] It has been suggested that the introduction of specialist diabetes pharmacists can support the implementation of insulin-prescribing interventions and decrease the percentage of insulin prescribing errors.[55] In this study, although the role of specialist diabetes nurses was reported in all the activities required to treat elevated BG using VRIII, nothing was mentioned about the role of specialist diabetes pharmacists in treating elevated BG using VRIII.

Adaptations to work was part of everyday work. Although the general thinking between participants was about errors and how to avoid them (Safety I), guideline developers explicitly acknowledged the occurrence of intentional deviation from guidelines, as patients' treatment should be individualised based on their situation. Nurses usually anticipate the needs of patients prior to surgery and sometimes proactively ask for a VRIII prescription, but doctors do not always provide such prescriptions as doing so may not be appropriate for the patient. There seems to be a need for careful thinking about flexibility and trade-offs in practice, and to set and define patient safety boundaries. These results reflect those of Vos *et al*, which showed that some behaviours that might be considered deviations from best practice when administering intravenous infusions resulted from reasoned clinical judgement by nurses with the aim of improving patient care.[56]

The HTA provided a better understanding from multiple perspectives of the use of VRIII, and of organisational influences such as how policies and guidelines were written, what was permitted, and how mandatory training was expected to be conducted. These results are broadly consistent with those of Raduma-Tomàs *et al*, who found that the application of the HTA provided a detailed description of the doctors' handover process, enabled the identification of strengths and weaknesses in the performance of handover activities, and allowed for specific problems to be targeted for improvement.[57] HTA has been used in health information technology by modifying existing designs or creating new ones.[58 59] Roosan *et al* used HTA and interactive infographics to develop a mobile prototype designed to deliver the patient package-insert information for the medication risperidone in an interactive way that helped patients gain an improved overall knowledge of the medication.[58] Another study used HTA to assess the effect of implementing new health information technology on the workflow of the medication administration process.[60] Its analysis of the HTA diagrams resulted in providing 15 recommendations for healthcare facilities to facilitate the transition to the new health information technology system.[60] The developed HTA could serve as an effective form of system documentation, enable guidelines developers to redesign guidelines and protocols based on the developed HTA, and help software engineers to gain familiarity with the tasks required while using VRIII in a systematic way which may enhance the design and usability of electronic systems as well as their ability to support individual/organisational contexts of use.

Clinical implications

WAI surrounding the use of VRIIIs was mainly related to the production, implementation and use of VRIII guidelines used in the study hospital. As the guidelines were implemented and used as part of the ePMA system, system designers in the study site may be able to use the developed HTAs to understand which trigger point of clinical care they can use to change and improve patient safety. For example, the study found that the ePMA system was not designed to show nurses the order in which fluids need to be administered—which makes it difficult for nurses to make the appropriate decisions. System designers might reduce the confusion by redesigning the ePMA system in a way that would enable doctors to prescribe intravenous fluids in a certain order and nurses to receive intravenous fluids prescriptions as graphs plotted from a timeline perspective.[61] Data visualisation can reduce cognitive load and the amount of information needed to be searched before making decisions.[62 63] A recent study found that developing a web-based timeline software, that graphically displays administered medication (y-axis) against time (x-axis), improved healthcare practitioners' interactions with the medical record system.[63] The graphical timeline software allowed healthcare practitioners to click on a medication name to display specific dosing and timing which resulted in reducing the time spent on medication review and easing the viewing of medication administration.[63] In the study site, developing an intravenous fluids graphical timeline software that shows the order of administering the prescribed intravenous fluids may reduce the confusion in administering intravenous fluids and improve confidence in deciding the order of intravenous fluids administration without delay.

Another example of a trigger point of care that might be improved is the task of frequent BG monitoring, especially given the growing challenges facing the NHS, for example, the shortage of healthcare practitioners and the current pressure forced on healthcare practitioners by the Coronavirus (COVID-19) pandemic,[64 65] which makes it difficult for this task to be conducted hourly. Evidence suggests that in-hospital use of continuous glucose monitoring (CGM) provides a practical alternative to frequent inpatient fingerstick testing. CGM works by inserting a sensor subcutaneously to measure the glucose level in the interstitial fluid, and results are provided every 5–10 min, 24 hours a day.[64] CGM incorporates predictive alerts for hypoglycaemia or hyperglycaemia which can be directly integrated into the electronic health record to alert the healthcare practitioners before the glucose sensor reaches the low or high threshold.[66] Considering the implementation of this technology may decrease the burden of glucose monitoring for healthcare practitioners and decrease the risk of hypo/hyperglycaemia events.

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Strengths and limitations

The application of HTA revealed the importance of in-depth understanding of how WAI and how guidelines are used to treat elevated BG using VRIII. Methodologically, this is the first study to explore WAI in relation to the use of VRIII using the HTA. Future research can build on insights from the study findings, and indicate how and where within the BG treatment process safety challenges might occur, thus allowing for specific challenges to be targeted and extraordinary work/adaptations to be highlighted to improve patient safety when using VRIII. Limitations associated with this study include the subjectivity of the healthcare professionals who participated in the FGs. The low number of staff who participated, especially in FGs 2 and 3, means that this analysis may not represent the perspectives of all the staff who use VRIII. Other participants might have given different views on the process of using VRIII. However, by purposive sampling of a diverse range of practitioners, this risk may have been somewhat mitigated. The purpose of qualitative studies is not to replicate or generalise the findings, however, qualitative studies are concerned with credibility and transferability.[67] Although the results from qualitative studies of small sample size may not always statistically represent the whole population of interest; they are qualitatively transferable. In this study, credibility and transferability were ensured by using a member check technique to confirm the accuracy of the developed HTAs, data triangulation using two data sources (documents and FGs) and thorough, detailed description of the contexts relating to the use of VRIIIs and the participants' accounts. Finally, it is necessary to acknowledge that guidelines discussed in this study were implemented a number of years ago and participants were not given a topic guide prior to the discussions hence there could be recall bias. In hindsight, it would be better to provide participants with key discussion topics, so they have time to consider past events before the FG meetings.

CONCLUSION

This study set out to understand from various perspectives how VRIII were expected to be used to treat elevated BG in the clinical environment. Using the HTA methodology, a detailed and systematic description of the tasks needed to use VRIII was successfully developed. The novel exploration of WAI within this context has important implications, revealing that the tasks required to treat elevated BG using VRIII are far more complex than merely implementing and adhering to national guidelines. Specifically, the complexity was found in various tasks/subtasks including understanding the context, prescribing intravenous fluids using ePMA and BG monitoring frequency. These complexities have been shown herein to play a key role and have possible broader implications in different healthcare context with similar challenges. Various strategies were expected to be used to enhance safety while using VRIII, among them training and intentional deviations/adaptations. However, further work is required to extend the scope for understanding how VRIII is used by assessing the impact and efficacy of the reported strategies on the actual process of using VRIII. The study results provided a deep understanding of the reality of WAI. The next stage is to conduct video observations[20] in order to understand how guidelines are used in practice, situations where the guidelines could not be delivered as written, type of challenges and context-dependent adaptations and to explore the gap/misalignments between WAI and WAD in order to find strategies to minimise the gap to improve patient care delivery.

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Contributors MHI, RL, KR, CC and FG conceived and designed the study. CC and MHI facilitated the recruitment of the participants. MHI was responsible for data collection with support and guidance from RL, CC and KR. MHI, RL and KR coded and analysed the data. MHI drafted the initial manuscript and the HTA. All authors edited the HTAs and CC extensively reviewed and commented on the HTA. All authors extensively edited drafts of the manuscript and accepted the final version of the manuscript.

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