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Understanding the causes of intravenous medication administration errors in hospitals: a critical incident study

Running title: Understanding the causes of intravenous medication administration errors

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ABSTRACT

Aims

Intravenous (IV) medication administration errors (MAEs) pose a greater threat to patient safety when compared to doses administered using other routes. The aim of this study was to investigate the causes of IV MAEs in hospitals.

Methods

Semi-structured interviews were conducted using the Critical Incident Technique with 20 nurses working in two NHS hospitals in England. Participants were identified and recruited using purposive sampling at each study site before being asked to discuss at interview perceived causes of IV MAEs that they had been directly involved with. Transcribed interviews underwent analysis using the Framework approach and categorisation according to themes from Reason's model of accident causation.

Results

In total, 21 IV MAEs were discussed containing 23 individual active failures which included slips and lapses (n=10), mistakes (n=9) and deliberate violations of policy (n=4). Each active failure was associated a range of error and violation provoking conditions. The working environment was implicated when nurses lacked healthcare team support and/or were exposed to a perceived increased workload during ward rounds, shift changes or emergencies. Nurses frequently reported that the quality of IV dose checking activities was compromised due to high perceived workload and working relationships. Nurses described using approaches such as subconscious functioning and prioritising to manage their duties, which at times contributed to errors.

Conclusions

Complex interactions between active and latent failures can lead to IV MAEs in hospitals. Future interventions may need to be multimodal in design in order to mitigate these risks and reduce the burden of IV MAEs.

Strengths and limitations of this study

- This is the first study to use qualitative interviewing with the critical incident technique to explore the underlying causes of IV MAEs in UK hospitals.
- Using human error theory to present interview data, different active failures were found to be associated with their own combination of error and violation provoking conditions concerning the patient, task, healthcare team, individual nurse, related equipment and working environment.
- A unique insight into everyday practice was revealed when nurses in particular reported that problems with dose checking activities, the working mentality they adopted to meet the demands of their role and a lack of support or high workload at important time periods contributed to their errors.
- Evidence based recommendations for interventions designed to minimise IV MAEs in hospitals have been suggested.
- Although the sample size may limit generalizability of findings, saturation of themes was apparent during analysis of interview data.

INTRODUCTION

Median estimates show that between 5.1-12.8% of hospital admissions[1] and 1.8% of hospitalised patients[2] are affected by preventable ADEs. Medication errors (MEs) are a key contributor to ADEs, and commonly affect the prescribing and administration stages.[3] Medication administration errors (MAEs) affect a median of 19.1% of total opportunities for error (TOE) in hospitals,[4] with error rates varying depending on study methods, definitions and settings.[4,5] Those responsible for drug administration may also inherit MEs arising at earlier medication use stages (e.g. prescribing).[3,6]

MAEs affecting the intravenous (IV) route of administration appear much more frequent than for non-IV routes. A recent systematic review found that MAEs affected a median 85.9% (IQR 81.8-89.9%) of IV TOE in healthcare settings.[4] It has been estimated that the probability of making at least one MAE in IV doses is 73%[7] and that IV doses are five times more likely to be associated with a MAE than non-IV doses.[5] Patient harm associated with IV MEs is known to be much greater than for other errors.[8]

Understanding the underlying causes of MAEs is important for the design and implementation of successful remedial interventions[9] especially given the limited impact of those tested so far.[10] Despite the high prevalence of MAEs in hospitals, few have concentrated on studying their causes[9,11-14] with only two focusing solely on IV MAEs.[11,12] Both studies used direct observation of medicines administration and brief conversations with subjects as their data collection method which when compared to in depth interviews limits detailed investigation of underlying intent or mental processes.[9,11] Studies reporting available data on IV MAE causes cite contributory factors including high workload/rushing,[11-13] poor supervision,[11] knowledge and training deficiencies,

distractions and interruptions, inadequate communication and policies/procedures, sharing bad practice and missing patients or inadequate/missing equipment.[11,12]

This study aimed to use the Critical Incident Technique (CIT) within semi-structured interviews to investigate the underlying causes of IV MAEs in two NHS hospitals.

METHODS

Setting and recruitment

Nurses were recruited between June 2012 and August 2013 working in two NHS teaching hospitals in the North West of England. Eligible nurses could work in ward or theatre based environments provided they were willing to discuss the causes of at least one IV MAE that they had been directly involved with.

Study contacts at each participating hospital distributed information about the study to nursing staff working on wards where IV medicines were administered frequently. Each interested nurse was given a study pack containing a letter of invitation, participant information leaflet and pre-interview questionnaire, and interviews were arranged once they returned the questionnaire to RNK. Participants were reassured that all outputs would be anonymised before providing written informed consent at each interview.

Data collection

Face-to-face semi structured interviews were conducted by RNK with each nurse participant in hospitals using the CIT.[16] The CIT has been used to collect empirical data on the causes of MEs[17,18] and explores problems by focusing on the intentions, behaviours and actions of those involved in specific situations, as opposed to estimations or generalisations.[16]

An interview guide was constructed based on the CIT and previous work investigating PEs[17] with only minor typographical changes being made after piloting at one study site. Background demographic information was collected before participants were asked to recall MAE(s) in detail (including nature and circumstances surrounding the MAE and perceived underlying causes). Nurses were invited to discuss both MAEs that reached the patient and errors that were caught and rectified before administration.

Categorisation of MAEs was based on established definitions[4,9,11,19] with labelling errors considered as 'wrong preparation errors'. Interviews lasted between 26-60 minutes, were conducted in private rooms at each hospital and were audio recorded and transcribed verbatim.

Data analysis

Interview transcripts were coded and analysed using the NVivo© computer software program (v10) according to the Framework analysis approach.[20] Framework analysis has been used in applied social research since the 1980's to understand human behaviours, and has more recently found favour in healthcare research due to its rigorous, transparent and systematic approach to qualitative data management and analysis.[20,21]

Reason's model of accident causation was used to inform the generation of a thematic framework based on emerging data from the interviews, and is summarised in Box 1 and Figure 1.[22,23] Data were coded as active failures and latent failures including error and violation provoking conditions and high level organisational decisions. The coding accuracy of each active failure was checked by a second author (SDW, JC and DMA), and the reliability of the coding framework was confirmed using 2 authors (SDW and JC) who independently extracted and analysed data for 10 interviews.

Ethical approval

The study was approved by the University of Manchester Research Ethics Committee (12028) and by the Research and Development departments of each participating NHS hospital trust.

Box 1: Reason's model of accident causation

In this model accidents such as IV MAEs arise when defensive barriers which protect medication administration processes from subversion are compromised. This can result from the actions or omissions of those on the front lines (e.g. nurses), which are called active failures, as well as latent failures affecting the wider system in which they work. Latent failures arise primarily from decisions at a higher organisational level (e.g. hospital managers) which may be flawed, influenced by wider goals or limited by regulatory or financial constraints. These decisions can weaken defences whilst also influencing the working conditions of healthcare staff such as nurses to make them more hazardous, thereby creating error and violation provoking conditions (see figure 1). Latent failures do not immediately lead to accidents; instead they lie dormant for long periods of time and may only be revealed when they combine with active failures in particular circumstances to cause accidents. Active failures can be categorised at the operator level according to intention, planning and execution and include slips and lapses (plan is adequate, but failure in execution), mistakes (plan is inadequate) and violations (intentional deviations from recommended practice). Although active failures may occur frequently their effects on defences are immediate and short lived; however the presence of any latent failures increases their frequency and the likelihood that their effects cause an accident such as an IV MAE to occur.

RESULTS

Twenty nurses were interviewed and 21 individual IV MAEs were discussed (see Table 1). The MAEs contained descriptions of 23 active failures, of which 9 were mistakes (5 knowledge based, 4 rule based), 6 were slips, 4 were lapses and 4 were deliberate violations of policy. Six different error and violation provoking conditions were identified: problems with the patient; the individual nurse; the task of drug administration; the healthcare team; the working environment and relevant equipment. Latent conditions were discussed as wider organisational decisions.

Table 1: Summary of study participants and reported IV MAEs

Participant code	Gender	Years since qualification[+]	Environment at time of MAE	Type of MAE	Medication class	Active failure(s)
N01	F	0-4	Ward	Wrong rate	Respiratory	Slip
N02	F	5-9	Ward	Wrong dose	Cardiovascular	KBM
N03	M	0-4	Ward	Wrong drug*[†]	Antimicrobial	Violation
N04	F	0-4	Ward	Wrong dose	Endocrine	Slip
N05	F	10+	Ward	Wrong rate	Electrolyte	Slip
N06	F	0-4	Ward	Wrong rate	Cardiovascular	KBM
N07	F	5-9	Ward	Wrong rate	Antimicrobial	KBM
		0-4	Ward	Wrong admin. technique	Cardiovascular	Lapse
N08	F	0-4	Ward	Wrong drug[†]	Antimicrobial	Lapse
N09	F	0-4	Ward	Wrong rate	Respiratory	RBM
N10	F	0-4	Ward	Wrong dose*	Cardiovascular	KBM
N11	M	5-9	Ward	Wrong drug*[†]	Antimicrobial	Violation
N12	F	0-4	Theatre	Wrong preparation[Δ‡]	CNS	Violation (x2)
N13	M	10+	Ward	Wrong preparation	Antimicrobial	KBM
N14	F	10+	Ward	Unordered drug[Δ†]	Endocrine	Slip
N15	F	10+	Ward	Extra dose* [Δ†]	CNS	RBM
N16	F	0-4	Ward	Wrong rate	Antimicrobial	Slip
N17	F	10+	Ward	Wrong preparation[‡]	Cardiovascular	Lapse
N18	F	5-9	Ward	Wrong rate	Cardiovascular	RBM
N19	F	10+	Theatre	Wrong preparation[Δ‡]	CNS	Slip, RBM
N20	F	10+	Theatre	Wrong dose	Cardiovascular	Lapse

+ = Number of years after qualified/licensed as a nurse that IV MAE occurred
* = Indicates occasions where nurses prepared and/or administered prescribing errors
† = Wrong drug, wrong patient, unordered drug and extra dose errors are considered 'unauthorised drug errors'
Δ = Indicates occasions where a complex chain of events involving different professional groups was involved
‡ = Indicates wrong label errors within wrong preparation group
Admin. = administration; CNS = central nervous system; F = female; IV = intravenous; KBM = knowledge based mistake; M = male; MAE = medication administration error; RBM = rule based mistake

Active failures

Casual attitudes toward dose checking were often discussed in relation to slips, whereas execution failures shared common causal elements in equipment design (e.g. look-a-like medicines), distractions and familiarity with patients. One nurse reported how distractions adversely affected her when checking a pump infusion rate:

"[…] ward rounds going on […] the patients are buzzing and everyone's asking you for handover and they're wanting patients out the ward and all this to do and I think to be honest there was too much going on, and the fact that someone was standing talking to me just kind of like, took my attention away at the time." (N16, female, 0-4 years (qualified as a nurse when IV MAE occurred))

Knowledge based mistakes (KBMs) occurred when participants encountered novel or infrequent challenges and lacked sufficient knowledge, as one nurse described:

"[…] I didn't know that vancomycin given too quickly could cause that reaction [red man syndrome] at all. So you just…that's something else maybe my knowledge of that wasn't, kind of, good enough." (N07, female, 5-9 years)

When faced with knowledge gaps, nurses either lacked or chose not to access support resources due to a variety of reasons which included challenging professional relationships, high perceived workload and application of incorrect actions which were based on prior experiences.

Rule based mistakes (RBMs) occurred when one nurse successfully applied a flawed checking process for high risk drugs or when others misapplied normally good rules regarding dosage adjustments for continuous infusions or for prescription checking activities. Infusion pump design, application of past experience, high perceived workload and local working practices were also implicated as contributory factors.

Most violations hinged on a decision not to challenge or question another member of the healthcare team when uncertain as to either the legibility of a prescription or whether to administer a drug without it being checked. One nurse described how their knowledge of the condition being treated and their relationships with other staff members influenced the decision not to clarify an illegible prescription:

"[…] because of the clinical context I was like […] I know meningitis, I know ceftriaxone, […] and showing [the drug to] my peer and […] I trust that person implicitly. […] because I should've just said well, to the prescriber who wasn't there, […] would you re-prescribe this please, it's illegible. And you'd have to take grief off them […] And that is policy, that's what one should do. The problem with policy is that it doesn't take into the individuals accounts that the patient needs the antibiotic promptly. […] And it's a real balance, especially in the moment, in the clinical mind set what will take precedent." (N11, male, 5-9 years)

Error and violation provoking conditions

The patient.

The increase in workload and associated distractions which accompanied dealing with clinically deteriorating patients or their relatives either individually or collectively during busy shifts commonly contributed to slips and lapses. In some cases, workload pressures combined with nurses' concerns for other patients to adversely affect concentration on the task at hand leading to lapses and slips:

"[…] so I was probably rushing as well due to the stress of getting everything done on time, and with me having quite a poorly patient I really wanted to be focusing on him […] Because this patient, the lady, she was stable apart from the high potassium […] She was absolutely fine otherwise. So he was my priority, really." (N04, female, 0-4 years)

The individual nurse.

Participants described making KBMs or execution failures when they were not familiar with infrequently used medicines. Conversely, overconfidence when ascertaining the identity of prescriptions or checking infusion pump inputs or prescriptions also led to MAEs, and arose due to familiarity with patients' treatment regimens, their physiological response to drug treatment or using infusion pump devices, as one nurse recalled when checking a prescription:

"[…] I didn't concentrate enough on the prescription […] I've known her for years she's been coming to the ward for years. I know exactly why she's coming in […] I had given her the drug myself [in the past] […] So somehow[…] I've allowed myself to see that [not concentrating] as acceptable." (N14, female, 10+ years)

Some newly qualified nurses described their lack of confidence and willingness to challenge others' decisions which contributed to IV MAEs. Perceptions of team hierarchy contributed to these decisions when nurses thought that doctors did not make mistakes or that they would inform them of important information personally (meaning they would not need to check the patient's medical notes). Others reported how they wanted to be perceived as managing their role but that in reality they struggled with workload, with two mentioning that fear of looking incompetent explained this behaviour. These opinions tended to change as the nurse grew in experience and felt confident to challenge others. Junior nurses in particular described how they had learnt bad practices experientially from more senior colleagues on the ward over time.

When dealing with multiple competing priorities and high workloads, nurses described reverting to a subconscious level of functioning which relied upon experiential pattern recognition often referred to as "autopilot" (N09, female, 0-4 years). Violations and execution errors resulted whilst in this state as decisions were made instantaneously and with little conscious thought of the circumstances at the time. Nurses also reported a task focused approach where IV administrations were rushed, particularly before lunch breaks, shift

changes or between ward rounds, in order to focus attention on other tasks (e.g. poorly patients, other ward round duties) or reduce workload for others (e.g. on the next shift).

The healthcare team.

Illegible prescription and medical note documentation, prescribing using incorrect sections of the prescription chart and failing to record medication administration contributed to slips, mistakes and violations when nurses decided against or omitted looking at them or misinterpreted their meaning. Illegible documentation at times led some nurses to give higher importance to verbal communication with medical staff for patient care. However, verbal miscommunication also contributed to mistakes and lapses, particularly in noisy theatre environments.

Participants recognised that they did not check IV doses thoroughly if the prescription was written by a respected physician or the task was carried out with a trusted nursing colleague. The superior knowledge and confidence perceived to be held by more experienced nursing colleagues also contributed to junior staff accepting their decisions and not second-checking thoroughly, at times despite doubting the prescriptions' safety.

Nurses described how poor relationships with medical staff deterred them from clarifying ambiguous or possibly incorrect prescriptions; these perceptions were influenced by previous negative experiences of being pressured to administer, treated discourteously and not being understood. Perceptions of being beneath medical staff in the professional hierarchy were linked closely with these experiences. The positive patient safety contribution of pharmacists was often dependent on them being present on the ward when nurses needed them. Experiences of limited accessibility to pharmacists and/or doctors contributed to two violations, two mistakes and one lapse, when nurses either could not contact them or decided against doing so based on prior experience.

Risky practice norms contributed to MAEs and included dividing checking roles such that the medication was never checked by two people, preparing and administering multiple IV medications simultaneously and, as one nurse described, administering all evening IV doses before shift change which pressurised her and promoted a task based approach to IV administration, leading eventually to a lapse:

"So being new myself it was drummed into me that we got the IV medications out before the night shift came on. So to me come eight o'clock, the night shift was starting […] So I felt pressure that I had to get them [IV doses] all out before they came out of the staff room [after shift hand over]." (N08, female, 0-4 years)

The working environment.

Noisy, chaotic and busy working environments pressurised and distracted nurses, leading them to rush tasks and fail to check prescriptions or dose preparation adequately. In one account, end of shift pressures combined with the ward layout and a temporary staff shortage encouraged a nurse to use time saving techniques when administering IV medicines on her own:

"[…] it was hand over period. One nurse went in to hand over and the other nurse was dealing with another patient in the bay and I was left to make up the IVs […] That's why I took them [medication trays] both together [for second checking] because it was the furthest away bay, so I thought to save time […] it was easier to get her to check them both […] Obviously not checking the things properly resulted in the error." (N08, female, 0-4 years)

Perceived high workload also contributed to mistakes and violations, and was increased due to temporary staff shortages, busy shifts, being responsible for more sick patients and inadequate staff skill mix. One nurse considered workload and other contextual factors when deciding whether to challenge an illegible prescription:

"[…] you'd be thinking, I need to get these medicines finished, because in an hour and a half's time, I've got my lunch time drugs to get out. So, that would have been a factor [in not clarifying an illegible prescription]." (N03, male, 0-4 years)

Interruptions and distractions contributed to a total of 10 IV MAEs, all but one (KBM) of which were execution failures. Participants described dividing their attention whilst conversing with patients, their relatives and other health care professionals. Distractions also originated from all other error and violation producing conditions.

Related equipment.

Ambiguous or obstructed dosage adjustment/checking interfaces on infusion pumps facilitated administration rate and dose errors via slips, mistakes and violations. In two cases, medicines required dose calculations which led to KBMs; in one account the medication vial was formulated for adults and the dose had to be converted for paediatric use. Look and sound-a-like medicines featured when nurses applied rules based on pattern recognition and consensus between colleagues or picked up the wrong product whilst distracted, as described below:

"[The medicines looked] absolutely similar, except for the writing [on the label] […] They were both in the same syringes." (N05, female, 10+ years)

The task.

The majority (n=17) of respondents described a failure in either their individual IV dose checking processes or the approach used when double checking with a nurse colleague as important contributors to IV MAEs. Weaknesses manifested as failures to read prescriptions properly, seek support, challenge prescribers and question the decisions of nursing colleagues, often despite personal doubts. A variety of other problems exposed the frailties of current IV dose checking practices which included individual overconfidence and distraction,

patient illness severity, high workload and interruptions, intra- or inter professional relationships and inappropriate local working practices. One nurse described how some of these error and violation provoking conditions influenced her when double checking IV doses for senior colleagues:

"[…] with the nature of the ward and it being so busy, I think it's becoming just a bit of a habit to people to just check the expiry date, check it's the right drug and then yeah, it's fine […] up until this incident I'd still say that if a sister asked me to check something, I would check it by the look of it […] she'll have done it right." (N04, female, 0-4 years)

Wider organisational decisions

Latent conditions were reported as a lack of availability of supportive resources for safe IV dosing such as drug reconstitution guidelines as well as insufficient access to medicines and other healthcare professionals during evenings and weekends. Logistical issues concerning the balance between new patient admissions and discharges and the timing of medication rounds also featured due to their negative effects on workload. Junior nurses mentioned that controlled access to IV administration as an undergraduate would have given them greater experience and confidence, thus preparing them more adequately for the demands of practice.

DISCUSSION

This study has found that hospital nurses' IV MAEs occur largely due to the error and violation provoking environment in which they work. A key strength of this study is that it is the first to focus on investigating the causes of IV MAEs using interview based CIT to generate detailed error accounts, and that data analysis was carried out using human error theory which facilitated identification of a range of systems failures. Depending on which active failure a nurse made, a different combination of error and violation provoking conditions were responsible, though considerable overlap existed as latent failures were closely linked.

Implications of findings

Active failures and error and violation provoking conditions.

Execution failures most often occurred when nurses were working in familiar surroundings on routine tasks, but were either distracted or experienced changes in their immediate environment (e.g. emergencies)[23] which is consistent with the MAE literature which has studied these failures.[9,11,12,18] Unlike prescribing errors,[24] execution failures causing IV MAEs described by participants were often not identified and corrected before administration to patients.

KBMs had roots in lack of knowledge and experience of using medicines[9,11,12,17,18] but were also dependent upon the quality of checking processes and whether nurses were able or chose to access supportive resources. A recent review of interventions designed to reduce MAEs in hospitals reported that education, training and increased access to supportive resources generally showed positive results.[10]

Accounts of violations revealed insights into intra-and inter-professional relationships and how nurses made clinical judgements in practice. Others have also identified the risks posed by violations in leading toward MAEs[9,25] with this active failure appearing frequently in IV MAEs.[11,12,18]

The collective accounts of nurse participants reveal that a number of health care team and working environment related conditions contributed to multiple active failure types. Nurses were the inheritors of prescribing errors made by other team members leading to MAEs (mistakes and violations), findings which have also been acknowledged by others investigating the origins of related ADEs.[3] There is growing interest in the effect of interruptions and distractions on patient safety, and this study builds on previous work in associating them with MAEs.[9] Previous efforts to reduce the impact of interruptions whilst administering medication show little evidence for improvements in error rates[26] and nurses in this study also voiced mixed opinions towards these strategies. Attention now appears to be shifting towards understanding the origins and management of interruptions.[27,28] Future research could build on the principle that some interruptions contribute positively toward patient care and instead focus on empowering and training nurses in interruption management.[26-28]

Timing of medicines administration.

Timing dependent contextual influences were shaped by local working norms and the nurses' desire to improve patient care, and were crucial contributory factors to IV MAEs. At times, nurses rushed tasks, cut corners and worked subconsciously as they felt under pressure to administer IV doses in order to attend concurrent ward rounds, to clear outstanding tasks for the next shift, to cover others' workload whilst they were in shift hand over, to meet the demands of medical staff or to respond to emergency situations. Whilst efforts to improve

shift hand over have shown positive results for medical errors,[29] no such interventions have yet been tested robustly for their effects on MAEs.[10]

Interestingly, workload was not mentioned as a contributory factor for the KBM and violation that occurred on weekends, and instead a lack of access or decision not to utilise supportive resources (medical and pharmacy staff) normally present during weekdays featured most strongly. Few have sought to determine whether MAE or related outcomes are more prevalent on weekends.[30]

Checking processes.

Although inadequate checking processes have been reported previously as a contributory factor to error,[31-34] these factors do not feature strongly in previous investigations of IV MAE causes[9,11,12] or as a part of robust interventions designed to reduce MAEs.[10] Checking exercises failed when nurses assumed over-competence and trust in each other or medical staff, were distracted by other duties, approached the administration task over-confidently without checking or could not or decided against accessing additional support. Earlier research in nursing[33,34] and medicine[17] have acknowledged similar issues regarding over-reliance on colleagues.

Current UK nursing standards for medicines management do not require all IV dose administrations in hospitals to be second checked or all dose calculations to be independently verified, nor do they specify when checking process should take place.[35] However, 85% of English NHS hospitals have a double checking policy for IV doses.[36] The majority of nurses in this study were unsure or gave conflicting accounts as to what they perceived to be correct checking policy, perhaps indicating a lack of understanding of this process.[33] As the majority of drug calculations may not be done independently[32] and the effect of double checking more generally on MAE rates in unclear,[31] a fundamental principle guiding

remedial approaches should perhaps be to stress the importance of equal responsibility between two practitioners involved, and that nurses of any grade should be empowered to challenge others given the fallibility of human nature.[34]

Task prioritisation.

Nurses described how the working environment often resulted in prioritisation of tasks at a subconscious level using experience in order to manage their duties, as they perceived that they had little time to complete all their work or stop to think about what they were doing. Mental workload has received little attention in previous MAE research.[9,11,12,18] This led to some considering drug administration as a task of less importance when compared to other duties or overall shift goals and therefore rushed to administer so they could move onto other duties. Others were rendered susceptible to inappropriate application of pattern recognition or missing important steps in maintaining safety whilst distracted.

Decision making by nurses during IV medication administration has been studied[37] as have the underlying theoretical principles behind such behaviours.[38] Nurse respondents shared beliefs with those from earlier work regarding how patient advocacy, a sense of time pressure and familiarity with their patients contributed to their decision making during administration.[37] However, these decision making investigations predominantly tried to understand how nurses maintain safety during medication administration rather than what compromises safety.

Limitations

Data collection relied upon nurses self-reporting and recounting past IV MAE events which increases the risk of recall and hindsight bias.[39] Social desirability bias[40] was minimised by using CIT as nurses were encouraged to explore their actual behaviours and describe

circumstances at the time in detail. Nurses openly accepted blame for their errors and at times required prompting to reveal latent failures which could have reduced attributional bias.[41] The use of a small sample size limits the generalizability of the findings.

CONCLUSION

This critical incident study has revealed the complex interactions between active and latent failures that underpin the emergence of IV MAEs in UK hospitals. Depending on the active failure made by front line staff, a number of a range of error and violation provoking conditions are often present. Three of these conditions were found to contribute to most identified MAEs: these were the dose checking activities carried out by nursing staff, the mental workload of nurses in order to manage the demands of their role, and the timing of ward based activities such as shift changes as well as the shift patterns of healthcare staff during weekends. This evidence suggests that a number of complex and multifaceted novel interventions may be required in order to reduce the burden of IV MAEs in hospitals.

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Competing interests

All the authors have no competing interests to declare. This work has not been posted or published elsewhere in its entirety with the exception of RNK's Doctor of Philosophy (PhD) thesis. An abstract summarising the study will soon be presented at the European Drug Utilization Research Group (EuroDURG) Annual Scientific Meeting (August 2014, Groningen, The Netherlands).

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Contributions

Design of study: all authors. Participant recruitment: RNK, SDW. Data collection: RNK. Data transcription: RNK and authorised external transcribing company. Data extraction: RNK, SDW, JC. Analysis of data: RNK. Preparation of manuscript: RNK. Review of manuscript: all authors.

Data sharing statement

No additional data available.

Figure legends

Figure 1: Reason's model of accident causation as applied to medication administration error research

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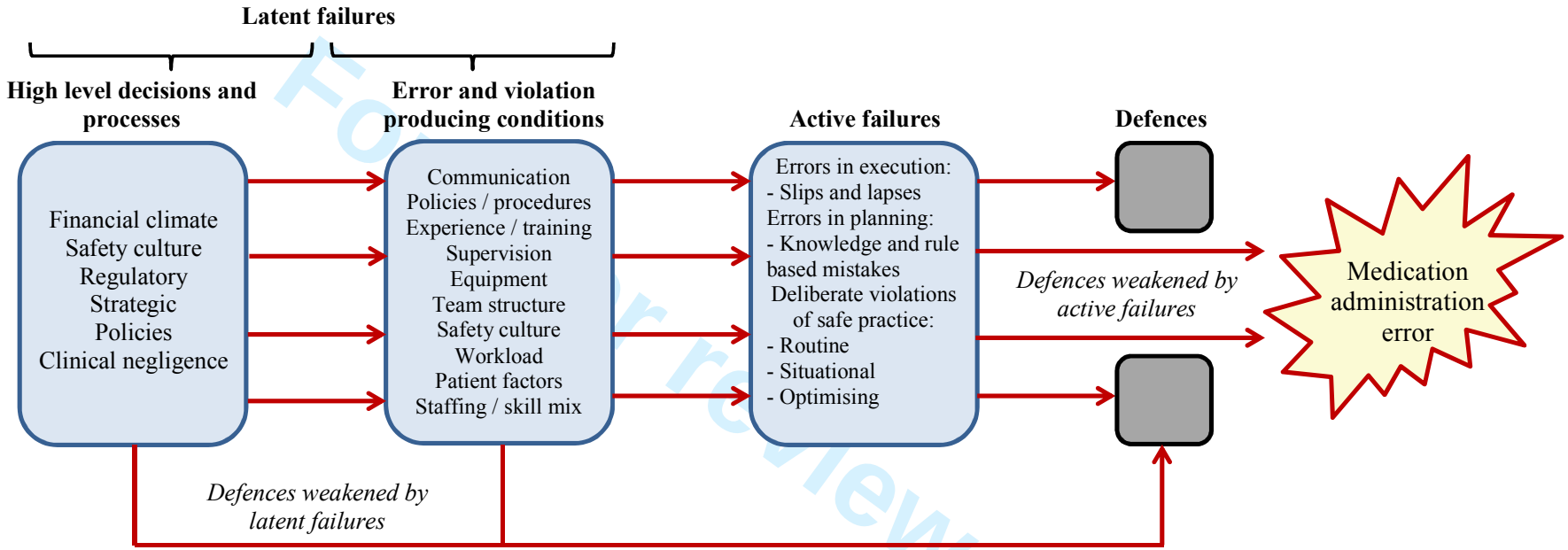

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Understanding the causes of intravenous medication administration errors in hospitals: a qualitative critical incident study

Running title: Understanding the causes of intravenous medication administration errors

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ABSTRACT

Objectives: To investigate the underlying causes of intravenous (IV) medication administration errors (MAEs) in National Health Service (NHS) hospitals.

Setting: Two NHS teaching hospitals in the North West of England.

Participants: Twenty nurses working in a range of inpatient clinical environments were identified and recruited using purposive sampling at each study site.

Primary outcome measures: Semi-structured interviews were conducted with nurse participants using the critical incident technique, where they were asked to discuss perceived causes of IV MAEs that they had been directly involved with. Transcribed interviews were analysed using the Framework approach, and emerging themes were categorised according to Reason's model of accident causation.

Results: In total, 21 IV MAEs were discussed containing 23 individual active failures which included slips and lapses (n=11), mistakes (n=8) and deliberate violations of policy (n=4). Each active failure was associated a range of error and violation provoking conditions. The working environment was implicated when nurses lacked healthcare team support and/or were exposed to a perceived increased workload during ward rounds, shift changes or emergencies. Nurses frequently reported that the quality of IV dose checking activities was compromised due to high perceived workload and working relationships. Nurses described using approaches such as subconscious functioning and prioritising to manage their duties, which at times contributed to errors.

Conclusions: Complex interactions between active and latent failures can lead to IV MAEs in hospitals. Future interventions may need to be multimodal in design in order to mitigate these risks and reduce the burden of IV MAEs.

Strengths and limitations of this study

- This is the first study to use qualitative interviewing with the critical incident technique to explore the underlying causes of IV MAEs in hospitals.
- Using human error theory, different active failures were found to be associated with their own combination of error and violation provoking conditions concerning the patient, task, healthcare team, individual nurse, related equipment and working environment.
- A unique insight into everyday practice was revealed when nurses in particular reported that problems with dose checking activities, the working mentality they adopted to meet the demands of their role and a lack of support or high workload at important time periods contributed to their errors.
- Theory-based recommendations for interventions designed to minimise IV MAEs in hospitals have been suggested.
- While the sample size may limit representativeness of findings to other health care settings, we included a range of nurses working in different environments, and data saturation was achieved.

INTRODUCTION

Median estimates show that between 5.1-12.8% of hospital admissions[1] and 1.8% of hospitalised patients[2] are affected by preventable ADEs. Medication errors (MEs) are a key contributor to ADEs, and commonly affect the prescribing and administration stages.[3] Medication administration errors (MAEs) can be defined as 'a deviation from the prescriber's medication order as written on the patient's chart, manufacturers' preparation/administration instructions, or relevant institutional policies', and affect a median of 19.1% of total opportunities for error (TOE) in hospitals,[4] with error rates varying depending on study methods, definitions and settings.[4,5] Those responsible for drug administration may also inherit MEs arising at earlier medication use stages (e.g. prescribing).[3,6]

MAEs affecting the intravenous (IV) route of administration appear much more frequent than for non-IV routes. A recent systematic review found that MAEs affected a median 85.9% (IQR 81.8-89.9%) of IV TOE in healthcare settings.[4] It has been estimated that the probability of making at least one MAE in IV doses is 73%[7] and that IV doses are five times more likely to be associated with a MAE than non-IV doses.[5] Patient harm associated with IV MEs is known to be much greater than for other errors.[8]

Understanding the underlying causes of MAEs is important for the design and implementation of successful remedial interventions[9] especially given the limited impact of those tested so far.[10] Despite the high prevalence of MAEs in hospitals, few have concentrated on studying their causes[9,11-14] with only two focusing solely on IV MAEs.[11,12] Both of these studies used direct observation of medicines administration and brief conversations with subjects as their data collection method which when compared to in depth interviews limits detailed investigation of underlying intent or mental processes.[9,11] Studies reporting available data on IV MAE causes cite contributory factors including high

workload/rushing,[11-13] poor supervision,[11] knowledge and training deficiencies, distractions and interruptions, inadequate communication and policies/procedures, sharing bad practice, lack of IV access for individual patients and deficiencies in the design of related equipment.[11,12]

This study aimed to use the critical incident technique (CIT) within semi-structured interviews to investigate the underlying causes of IV MAEs in two NHS hospitals.

METHODS

Setting and recruitment

Nurses were recruited between June 2012 and August 2013 working in two NHS teaching hospitals in the North West of England. Eligible nurses could work in ward or theatre based environments provided they were willing to discuss the causes of at least one IV MAE that they had been directly involved with.

Study contacts at each participating hospital distributed information about the study to nursing staff working on wards where IV medicines were administered frequently. Each interested nurse was given a study pack containing a letter of invitation, participant information leaflet and pre-interview questionnaire, and interviews were arranged once they returned the questionnaire to RNK. Participants were reassured that all outputs would be anonymised before providing written informed consent at each interview.

Data collection

Face-to-face semi structured interviews were conducted by RNK with each nurse participant in hospitals using the CIT.[15] A summary of the interview guide can be found in Box 1. The CIT has been used to collect empirical data on the causes of MEs[16,17] and explores problems by focusing on the intentions, behaviours and actions of those involved in specific situations, as opposed to estimations or generalisations.[15] These characteristics made the CIT a more useful data collection tool when compared with in depth interviewing, as it enabled high quality relevant data to be gathered from busy nursing staff.

An interview guide was constructed based on the principles of the CIT and previous work investigating PEs[16] with only minor typographical changes being made after piloting at one study site. Background demographic information was collected before participants were

asked to recall MAE(s) in detail (including nature and circumstances surrounding the MAE and perceived underlying causes). Nurses were invited to discuss both MAEs that reached the patient and errors that were caught and rectified before administration.

Categorisation of MAEs was based on established definitions,[4,9,11,18] with labelling errors considered as 'wrong preparation errors'. Interviews lasted between 26-60 minutes, were conducted in private rooms at each hospital and were audio recorded and transcribed verbatim.

Box 1: Summary of interview guide

Part One: Background

- Training background (including intravenous medication administration)
- Years qualified as a nurse
- Area of practice

Part Two: The intravenous medication administration error

- Error details (medication involved, error type, how was error discovered, did the error reach the patient)
- Circumstances at time of error (e.g. day of week, time of day, who else involved, location, physical/mental health, general workload, level of supervision, patient factors)
- Reasons for the error

Part Three: Reflecting on the error

- Changes to personal practice following the error
- Prevention of incident (what might have been put in place)

Data analysis

Interview transcripts were coded and analysed using the NVivo© computer software program (v10) according to the Framework analysis approach.[19] Framework analysis has been used in applied social research since the 1980's to understand human behaviours, and has more recently found favour in healthcare research due to its rigorous, transparent and systematic approach to qualitative data management and analysis.[19,20]

Reason's model of accident causation was used to inform the generation of themes within the Framework approach based on *a priori* knowledge [9] and emerging data from the interviews, and is summarised in Box 2 and Figure 1.[21,22] This model has been used elsewhere to study causes of MEs.[9,16,17,23,24] Data were coded as active failures and latent failures including error and violation provoking conditions and high level organisational decisions. The coding accuracy of each active failure was checked by a second author (SDW, JC and DMA), and the reliability of the coding framework was confirmed using 2 authors (SDW and JC) who independently extracted and analysed data for 10 interviews.

Ethical approval

The study was approved by the University of Manchester Research Ethics Committee (12028) and by the Research and Development departments of each participating NHS hospital trust.

Box 2: Reason's model of accident causation[21,22]

In this model accidents such as IV MAEs arise when defensive barriers which protect medication administration processes from subversion are compromised. This can result from the actions or omissions of those on the front lines (e.g. nurses), which are called active failures, as well as latent failures affecting the wider system in which they work. Latent failures arise primarily from decisions at a higher organisational level (e.g. hospital managers) which may be flawed, influenced by wider goals or limited by regulatory or financial constraints. These decisions can weaken defences whilst also influencing the working conditions of healthcare staff such as nurses to make them more hazardous, thereby creating error and violation provoking conditions (see Figure 1). Latent failures do not immediately lead to accidents; instead they lie dormant for long periods of time and may only be revealed when they combine with active failures in particular circumstances to cause accidents.

Active failures can be categorised at the operator level::

- Execution failures (plan is adequate to achieve outcome, but failure in execution):
  - Slips (observable actions and often associated with attention failures),
  - Lapses (internal events, often involving memory failure),
- Mistakes (plan is inadequate to achieve intended outcome, failures in problem solving):
  - Knowledge based (cannot use prior experience to solve a novel problem),
  - Rule based (misapply/omit a good rule or successfully apply a bad rule to solve a trained for problem), and
- Violations (intentional deviations from recommended practice (e.g. clinical procedures)).
  - Routine (e.g. cutting corners as habitual behaviour),
  - Optimizing (furthering personal rather task orientated goals),
  - Necessary (violation essential to perform task appropriately).

Although active failures may occur frequently their effects on defences are immediate and short lived; however the presence of any latent failures increases their frequency and the likelihood that their effects cause an accident such as an IV MAE to occur.

RESULTS

Twenty nurses were interviewed and 21 individual IV MAEs were discussed (see Table 1). The MAEs contained descriptions of 23 active failures, of which 8 were mistakes (5 knowledge based, 3 rule based), 7 were slips, 4 were lapses and 4 were deliberate violations of policy. Six different error and violation provoking conditions were identified: problems with the patient; the individual nurse; the task of drug administration; the healthcare team; the working environment and relevant equipment. Latent conditions were discussed as wider organisational decisions.

Table 1: Summary of study participants and reported IV MAEs

Participant code	Gender	Years since qualification+	Environment at time of MAE	Type of MAE	Did the error reach the patient	Medication class	Active failure(s)
N01	F	0-4	Ward	Wrong rate	Yes	Respiratory	Slip
N02	F	5-9	Ward	Wrong dose	Yes	Cardiovascular	KBM
N03	M	0-4	Ward	Wrong drug*†	Yes	Antimicrobial	Violation
N04	F	0-4	Ward	Wrong dose	Yes	Endocrine	Slip
N05	F	10+	Ward	Wrong rate	Yes	Electrolyte	Slip
N06	F	0-4	Ward	Wrong rate	Yes	Cardiovascular	KBM
N07	F	5-9	Ward	Wrong rate	Yes	Antimicrobial	KBM
		0-4	Ward	Wrong administration technique	Yes	Cardiovascular	Lapse
N08	F	0-4	Ward	Wrong drug†	Yes	Antimicrobial	Lapse
N09	F	0-4	Ward	Wrong rate	Yes	Respiratory	Slip
N10	F	0-4	Ward	Wrong dose*	No	Cardiovascular	KBM
N11	M	5-9	Ward	Wrong drug*†	Yes	Antimicrobial	Violation
N12	F	0-4	Theatre	Wrong preparation$^{\Delta\ddagger}$	Yes	CNS	Violation (x2)
N13	M	10+	Ward	Wrong preparation	Yes	Antimicrobial	KBM
N14	F	10+	Ward	Unordered drug$^{\Delta\dagger}$	Yes	Endocrine	Slip
N15	F	10+	Ward	Extra dose*$^{\Delta\dagger}$	Yes	CNS	RBM
N16	F	0-4	Ward	Wrong rate	Yes	Antimicrobial	Slip
N17	F	10+	Ward	Wrong preparation‡	Yes	Cardiovascular	Lapse
N18	F	5-9	Ward	Wrong rate	Yes	Cardiovascular	RBM
N19	F	10+	Theatre	Wrong preparation$^{\Delta\ddagger}$	Yes	CNS	Slip, RBM
N20	F	10+	Theatre	Wrong dose	Yes	Cardiovascular	Lapse

+ = Number of years after qualified/licensed as a nurse that IV MAE occurred
* = Indicates occasions where nurses prepared and/or administered prescribing errors (e.g. poorly written prescription)
† = Wrong drug, wrong patient, unordered drug and extra dose errors are considered 'unauthorised drug errors'
Δ = Indicates occasions where a complex chain of events involving different professional groups was involved
‡ = Indicates wrong label errors within wrong preparation group
Admin. = administration; CNS = central nervous system; F = female; IV = intravenous; KBM = knowledge based mistake; M = male; MAE = medication administration error; RBM = rule based mistake

Active failures

Casual attitudes toward dose checking were often discussed in relation to slips, whereas both types of execution failure shared common causal elements in equipment design (e.g. look-a-like medicines), distractions and familiarity with patients. One nurse reported how distractions adversely affected her when checking a pump infusion rate:

"[…] ward rounds going on […] the patients are buzzing and everyone's asking you for handover and they're wanting patients out the ward and all this to do and I think to be honest there was too much going on, and the fact that someone was standing talking to me just kind of like, took my attention away at the time." (N16, female, 0-4 years (qualified as a nurse when IV MAE occurred))

Knowledge based mistakes (KBMs) occurred when participants encountered novel or infrequent challenges and lacked sufficient knowledge, as one nurse described:

"[…] I didn't know that vancomycin given too quickly could cause that reaction [red man syndrome] at all. So you just…that's something else maybe my knowledge of that wasn't, kind of, good enough." (N07, female, 5-9 years)

When faced with knowledge gaps, nurses either lacked or chose not to access support resources due to a variety of reasons which included challenging professional relationships, high perceived workload and application of incorrect actions which were based on prior experiences.

Rule based mistakes (RBMs) occurred when nurses misapplied normally good rules regarding dosage adjustments for continuous infusions or for prescription checking activities. Infusion pump design, application of past experience, high perceived workload and local working practices were also implicated as contributory factors.

Most violations of procedures hinged on a decision not to challenge or question another member of the healthcare team when uncertain as to either the legibility of a prescription or

whether to administer a drug without it being checked. One nurse described how their knowledge of the condition being treated and their relationships with other staff members influenced the decision not to clarify an illegible prescription:

"[…] because of the clinical context I was like […] I know meningitis, I know ceftriaxone, […] and showing [the drug to] my peer and […] I trust that person implicitly. […] because I should've just said well, to the prescriber who wasn't there, […] would you re-prescribe this please, it's illegible. And you'd have to take grief off them […] And that is policy, that's what one should do. The problem with policy is that it doesn't take into the individuals accounts that the patient needs the antibiotic promptly. […] And it's a real balance, especially in the moment, in the clinical mind set what will take precedent." (N11, male, 5-9 years)

Error and violation provoking conditions

The patient.

The increase in workload and associated distractions which accompanied dealing with clinically deteriorating patients or their relatives either individually or collectively during busy shifts commonly contributed to slips and lapses. In some cases, workload pressures combined with nurses' concerns for other patients to adversely affect concentration on the task at hand leading to lapses and slips:

"[…] so I was probably rushing as well due to the stress of getting everything done on time, and with me having quite a poorly patient I really wanted to be focusing on him […] Because this patient, the lady, she was stable apart from the high potassium […] She was absolutely fine otherwise. So he was my priority, really." (N04, female, 0-4 years)

The individual nurse.

Participants described making KBMs or execution failures when they were not familiar with infrequently used medicines. Conversely, overconfidence when ascertaining the identity of prescriptions or checking infusion pump inputs or prescriptions also led to MAEs, and arose

due to familiarity with patients' treatment regimens, their physiological response to drug treatment or using infusion pump devices, as one nurse recalled when checking a prescription:

"[…] I didn't concentrate enough on the prescription […] I've known her for years she's been coming to the ward for years. I know exactly why she's coming in […] I had given her the drug myself [in the past] […] So somehow[…] I've allowed myself to see that [not concentrating] as acceptable." (N14, female, 10+ years)

Some newly qualified nurses described their lack of confidence and willingness to challenge others' decisions which contributed to IV MAEs. Perceptions of team hierarchy contributed to these decisions when nurses thought that doctors did not make mistakes or that they would inform them of important information personally (meaning they would not need to check the patient's medical notes). Others reported how they wanted to be perceived as managing their role but that in reality they struggled with workload, with two mentioning that fear of looking incompetent explained this behaviour. These opinions tended to change as the nurse grew in experience and felt confident to challenge others. Junior nurses in particular described how they had learnt bad practices experientially from more senior colleagues on the ward over time.

When dealing with multiple competing priorities and high workloads, nurses described reverting to a subconscious level of functioning which relied upon experiential pattern recognition often referred to as "autopilot" (N09, female, 0-4 years). Violations and execution errors resulted whilst in this state as decisions were made instantaneously and with little conscious thought of the circumstances at the time. Nurses also reported a task focused approach where IV administrations were rushed, particularly before lunch breaks, shift changes or between ward rounds, in order to focus attention on other tasks (e.g. poorly patients, other ward round duties) or reduce workload for others (e.g. on the next shift).

The healthcare team.

Illegible prescription and medical note documentation, prescribing using incorrect sections of the prescription chart and failing to record medication administration contributed to slips, mistakes and violations when nurses decided against or omitted looking at them or misinterpreted their meaning. Illegible documentation at times led some nurses to give higher importance to verbal communication with medical staff for patient care. However, verbal miscommunication also contributed to mistakes and lapses, particularly in noisy theatre environments.

Participants recognised that they did not check IV doses thoroughly if the prescription was written by a respected physician or the task was carried out with a trusted nursing colleague. The superior knowledge and confidence perceived to be held by more experienced nursing colleagues also contributed to junior staff accepting their decisions and not second-checking thoroughly, at times despite doubting the prescriptions' safety.

Nurses described how poor relationships with medical staff deterred them from clarifying ambiguous or possibly incorrect prescriptions; these perceptions were influenced by previous negative experiences of being pressured to administer, treated discourteously and not being understood. Perceptions of being beneath medical staff in the professional hierarchy were linked closely with these experiences. The positive patient safety contribution of pharmacists was often dependent on them being present on the ward when nurses needed them. Experiences of limited accessibility to pharmacists and/or doctors contributed to two violations, two mistakes and one lapse, when nurses either could not contact them or decided against doing so based on prior experience.

Risky practice norms contributed to MAEs and included dividing checking roles such that the medication was never checked by two people, preparing and administering multiple IV

medications simultaneously and, as one nurse described, administering all evening IV doses before shift change which pressurised her and promoted a task based approach to IV administration, leading eventually to a lapse:

"So being new myself it was drummed into me that we got the IV medications out before the night shift came on. So to me come eight o'clock, the night shift was starting […] So I felt pressure that I had to get them [IV doses] all out before they came out of the staff room [after shift hand over]." (N08, female, 0-4 years)

The working environment.

Noisy, chaotic and busy working environments pressurised and distracted nurses, leading them to rush tasks and fail to check prescriptions or dose preparation adequately. In one account, end of shift pressures combined with the ward layout and a temporary staff shortage encouraged a nurse to use time saving techniques when administering IV medicines on her own:

"[…] it was hand over period. One nurse went in to hand over and the other nurse was dealing with another patient in the bay and I was left to make up the IVs […] That's why I took them [medication trays] both together [for second checking] because it was the furthest away bay, so I thought to save time […] it was easier to get her to check them both […] Obviously not checking the things properly resulted in the error." (N08, female, 0-4 years)

Perceived high workload also contributed to mistakes and violations, and was increased due to temporary staff shortages, busy shifts, being responsible for more sick patients and inadequate staff skill mix. One nurse considered workload and other contextual factors when deciding whether to challenge an illegible prescription:

"[…] you'd be thinking, I need to get these medicines finished, because in an hour and a half's time, I've got my lunch time drugs to get out. So, that would have been a factor [in not clarifying an illegible prescription]." (N03, male, 0-4 years)

Interruptions and distractions contributed to a total of 11 IV MAEs, all but one (KBM) of which were execution failures. Participants described dividing their attention whilst conversing with patients, their relatives and other health care professionals. Distractions also originated from all other error and violation producing conditions.

Related equipment.

Ambiguous or obstructed dosage adjustment/checking interfaces on infusion pumps facilitated administration rate and dose errors via slips, mistakes and violations. In two cases, medicines required dose calculations which led to KBMs; in one account the medication vial was formulated for adults and the dose had to be converted for paediatric use. Look and sound-a-like medicines featured when nurses applied rules based on pattern recognition and consensus between colleagues or picked up the wrong product whilst distracted, as described below:

"[The medicines looked] absolutely similar, except for the writing [on the label] […] They were both in the same syringes." (N05, female, 10+ years)

The task.

The majority (n=17) of respondents described a failure in either their individual IV dose checking processes or the approach used when double checking with a nurse colleague as important contributors to IV MAEs. Weaknesses manifested as failures to read prescriptions properly, seek support, challenge prescribers and question the decisions of nursing colleagues, often despite personal doubts. A variety of other problems exposed the frailties of current IV dose checking practices which included individual overconfidence and distraction, patient illness severity, high workload and interruptions, intra- or inter professional relationships and inappropriate local working practices. One nurse described how some of

these error and violation provoking conditions influenced her when double checking IV doses for senior colleagues:

"[…] with the nature of the ward and it being so busy, I think it's becoming just a bit of a habit to people to just check the expiry date, check it's the right drug and then yeah, it's fine […] up until this incident I'd still say that if a sister asked me to check something, I would check it by the look of it […] she'll have done it right." (N04, female, 0-4 years)

Wider organisational decisions

Latent conditions were reported as a lack of availability of supportive resources for safe IV dosing such as drug reconstitution guidelines as well as insufficient access to medicines and other healthcare professionals during evenings and weekends. Logistical issues concerning the balance between new patient admissions and discharges and the timing of medication rounds also featured due to their negative effects on workload. Junior nurses mentioned that controlled access to IV administration as an undergraduate would have given them greater experience and confidence, thus preparing them more adequately for the demands of practice.

DISCUSSION

This study has found that hospital nurses' IV MAEs occur largely due to the error and violation provoking environment in which they work. Key strengths of this study are that it is the first to focus on investigating the causes of IV MAEs using interview based CIT to generate detailed error accounts, we achieved data saturation in the main emerging themes and that data analysis was carried out using human error theory which facilitated identification of a range of systems failures. Depending on which active failure a nurse made, different combinations of error and violation provoking conditions were responsible, though considerable overlap existed as latent failures were closely linked.

Implications of findings

Active failures and error and violation provoking conditions.

Execution failures most often occurred when nurses were working in familiar surroundings on routine tasks, but were either distracted or experienced changes in their immediate environment (e.g. emergencies)[22] which is consistent with the MAE literature which has studied these failures.[9,11,12,17] Unlike prescribing errors,[24] execution failures causing IV MAEs described by participants were often not identified and corrected before administration to patients.

KBMs had roots in lack of knowledge and experience of using medicines[9,11,12,16,17] but were also dependent upon the quality of checking processes and whether nurses were able or chose to access supportive resources. A recent review of interventions designed to reduce MAEs in hospitals reported that education, training and increased access to supportive resources generally showed positive results.[10]

Accounts of violations revealed insights into intra-and inter-professional relationships and how nurses made clinical judgements in practice. Others have also identified the risks posed by violations in leading toward MAEs[9,25] with this active failure appearing frequently in IV MAEs.[11,12,17]

The collective accounts of nurse participants reveal that a number of health care team and working environment related conditions contributed to multiple active failure types. Nurses were the inheritors of prescribing errors made by other team members leading to MAEs (mistakes and violations), findings which have also been acknowledged by others investigating the origins of related ADEs.[3] There is growing interest in the effect of interruptions and distractions on patient safety, and this study builds on previous work in associating them with MAEs.[9] Previous efforts to reduce the impact of interruptions whilst administering medication show little evidence for improvements in error rates[26] and nurses in this study also voiced mixed opinions towards these strategies. Attention now appears to be shifting towards understanding the origins and management of interruptions.[27,28] Future research could build on the principle that some interruptions contribute positively toward patient care and instead focus on empowering and training nurses in interruption management.[26-28]

Timing of medicines administration.

Timing dependent contextual influences were shaped by local working norms and the nurses' desire to improve patient care, and were crucial contributory factors to IV MAEs. At times, nurses rushed tasks, cut corners and worked subconsciously as they felt under pressure to administer IV doses. This pressure emerged from the need to attend concurrent ward rounds, to clear outstanding tasks for the next shift, to cover others' workload whilst they were in shift hand over, to meet the demands of medical staff or to respond to emergency situations.

Whilst efforts to improve shift hand over have shown positive results for medical errors,[29] no such interventions have yet been tested robustly for their effects on MAEs.[10]

Interestingly, workload was not mentioned as a contributory factor for the KBM and violation that occurred on weekends, and instead a lack of access or decision not to utilise supportive resources (medical and pharmacy staff) normally present during weekdays featured. Few have sought to determine whether MAE or related outcomes are more prevalent on weekends.[30]

Checking processes.

Although inadequate checking processes have been reported previously as a contributory factor to error,[31-34] these factors do not feature strongly in previous investigations of IV MAE causes[9,11,12] or as a part of robust interventions designed to reduce MAEs.[10] Checking exercises failed when nurses assumed over-competence and trust in each other or medical staff, were distracted by other duties, approached the administration task over-confidently without checking or could not or decided against accessing additional support. Earlier research in nursing[33,34] and medicine[16] have acknowledged similar issues regarding over-reliance on colleagues.

Current UK nursing standards for medicines management state that all IV dose calculations should be independently checked and that where possible IV administrations should be checked by a second registrant (without specifying exactly when checking should take place).[35] In England, 85% of NHS hospitals have a double checking policy for IV doses.[36] The majority of nurses in this study were unsure or gave conflicting accounts as to what they perceived to be correct checking policy, perhaps indicating a lack of understanding of this process.[33] As the majority of dose calculation second checks in one UK paediatric hospital were not independent[32] and the effect of double checking more generally on MAE

rates in unclear,[31] a fundamental principle guiding remedial approaches should perhaps be to stress the importance of equal responsibility between two practitioners involved, and that nurses of any grade should be empowered to challenge others given the fallibility of human nature.[34]

Task management.

Nurses described how the working environment often resulted in management of tasks at a subconscious level using experience in order to manage their duties, as they perceived that they had little time to complete all their work or stop to think about what they were doing. Mental workload has received little attention in previous MAE research.[9,11,12,17] This led to some considering drug administration as a task of less importance when compared to other duties or overall shift goals, causing them to rush administration so they could move onto other duties. Others were rendered susceptible to inappropriate application of pattern recognition or missing important checking steps in maintaining safety whilst distracted.

Decision making by nurses during IV medication administration has been studied[37] as have the underlying theoretical principles behind such behaviours.[38] The findings of this study reflect the work of other researchers which suggests that we manage and process information using Type 1 (predominant approach, using intuitive subconscious responses based on instinct and repetitive experiences) and Type 2 thinking modes (conscious, analytic responses which are slower), both of which are prone to cognitive biases that can lead to error.[39] Nurse respondents shared beliefs with those from earlier work regarding how patient advocacy, a sense of time pressure and familiarity with their patients contributed to their decision making during administration.[37] However, as these decision making investigations predominantly tried to understand how nurses maintain safety during medication administration, further work could focus on understanding which cognitive biases negatively

affect medication safety for nurses, and how practitioners can recognise and minimise them in their own practice.

Limitations

Data collection relied upon nurses self-reporting and recounting past IV MAE events which increases the risk of recall and hindsight bias.[40] Social desirability bias[41] was minimised by using CIT as nurses were encouraged to explore their actual behaviours and describe circumstances at the time in detail. Nurses openly accepted blame for their errors and at times required prompting to reveal latent failures which could have reduced attributional bias.[42] Recruitment of participants from two NHS hospitals may have limited the representativeness of the findings to other health care settings.

CONCLUSION

This qualitative critical incident study has revealed the complex interactions between active and latent failures that underpin the emergence of IV MAEs in UK hospitals. Depending on the active failure made by front line staff, a number of a range of error and violation provoking conditions are often present. Three of these conditions were found to contribute to most identified MAEs: these were the dose checking activities carried out by nursing staff, the mental workload of nurses in order to manage the demands of their role, and the timing of ward based activities such as shift changes as well as the shift patterns of healthcare staff during weekends. This evidence suggests that a number of complex and multifaceted novel interventions may be required in order to reduce the burden of IV MAEs in hospitals.

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Competing interests

All the authors have no competing interests to declare. This work has not been posted or published elsewhere in its entirety with the exception of RNK's Doctor of Philosophy (PhD) thesis. An abstract summarising the study was presented at the European Drug Utilization Research Group (EuroDURG) Annual Scientific Meeting (August 2014, Groningen, The Netherlands).

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Contributions

Conception of study: all authors. Design of study: all authors. Participant recruitment: RNK, SDW. Data collection: RNK. Data transcription: RNK and authorised external transcribing company. Data extraction: RNK, SDW, JC. Analysis of data: RNK. Preparation of manuscript: RNK. Review and approval of manuscript: all authors.

Data sharing statement

No additional data available.

Figure legends

Figure 1: Reason's model of accident causation as applied to medication administration error research

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Understanding the causes of intravenous medication administration errors in hospitals: a qualitative critical incident study

Running title: Understanding the causes of intravenous medication administration errors

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ABSTRACT

Objectives: To investigate the underlying causes of intravenous (IV) medication administration errors (MAEs) in National Health Service (NHS) hospitals.

Setting: Two NHS teaching hospitals in the North West of England.

Participants: Twenty nurses working in a range of inpatient clinical environments were identified and recruited using purposive sampling at each study site.

Primary outcome measures: Semi-structured interviews were conducted with nurse participants using the critical incident technique, where they were asked to discuss perceived causes of IV MAEs that they had been directly involved with. Transcribed interviews were analysed using the Framework approach, and emerging themes were categorised according to Reason's model of accident causation.

Results: In total, 21 IV MAEs were discussed containing 23 individual active failures which included slips and lapses (n=11), mistakes (n=8) and deliberate violations of policy (n=4). Each active failure was associated a range of error and violation provoking conditions. The working environment was implicated when nurses lacked healthcare team support and/or were exposed to a perceived increased workload during ward rounds, shift changes or emergencies. Nurses frequently reported that the quality of IV dose checking activities was compromised due to high perceived workload and working relationships. Nurses described using approaches such as subconscious functioning and prioritising to manage their duties, which at times contributed to errors.

Conclusions: Complex interactions between active and latent failures can lead to IV MAEs in hospitals. Future interventions may need to be multimodal in design in order to mitigate these risks and reduce the burden of IV MAEs.

Strengths and limitations of this study

- This is the first study to use qualitative interviewing with the critical incident technique to explore the underlying causes of IV MAEs in ~~UK~~ hospitals.
- Using human error theory ~~to present interview data~~, different active failures were found to be associated with their own combination of error and violation provoking conditions concerning the patient, task, healthcare team, individual nurse, related equipment and working environment.
- A unique insight into everyday practice was revealed when nurses in particular reported that problems with dose checking activities, the working mentality they adopted to meet the demands of their role and a lack of support or high workload at important time periods contributed to their errors.
- Theory-based recommendations for interventions designed to minimise IV MAEs in hospitals have been suggested.
- While the sample size may limit representativeness of findings to other health care settings, we included a range of nurses working in different environments, and data saturation was achieved.

INTRODUCTION

Median estimates show that between 5.1-12.8% of hospital admissions[1] and 1.8% of hospitalised patients[2] are affected by preventable ADEs. Medication errors (MEs) are a key contributor to ADEs, and commonly affect the prescribing and administration stages.[3] Medication administration errors (MAEs) can be defined as 'a deviation from the prescriber's medication order as written on the patient's chart, manufacturers' preparation/administration instructions, or relevant institutional policies', and affect a median of 19.1% of total opportunities for error (TOE) in hospitals,[4] with error rates varying depending on study methods, definitions and settings.[4,5] Those responsible for drug administration may also inherit MEs arising at earlier medication use stages (e.g. prescribing).[3,6]

MAEs affecting the intravenous (IV) route of administration appear much more frequent than for non-IV routes. A recent systematic review found that MAEs affected a median 85.9% (IQR 81.8-89.9%) of IV TOE in healthcare settings.[4] It has been estimated that the probability of making at least one MAE in IV doses is 73%[7] and that IV doses are five times more likely to be associated with a MAE than non-IV doses.[5] Patient harm associated with IV MEs is known to be much greater than for other errors.[8]

Understanding the underlying causes of MAEs is important for the design and implementation of successful remedial interventions[9] especially given the limited impact of those tested so far.[10] Despite the high prevalence of MAEs in hospitals, few have concentrated on studying their causes[9,11-14] with only two focusing solely on IV MAEs.[11,12] Both of these studies used direct observation of medicines administration and brief conversations with subjects as their data collection method which when compared to in depth interviews limits detailed investigation of underlying intent or mental processes.[9,11] Studies reporting available data on IV MAE causes cite contributory factors including high

workload/rushing,[11-13] poor supervision,[11] knowledge and training deficiencies, distractions and interruptions, inadequate communication and policies/procedures, sharing bad practice, lack of IV access for individual patients and deficiencies in the design of related equipment.[11,12]

This study aimed to use the critical incident technique (CIT) within semi-structured interviews to investigate the underlying causes of IV MAEs in two NHS hospitals.

METHODS

Setting and recruitment

Nurses were recruited between June 2012 and August 2013 working in two NHS teaching hospitals in the North West of England. Eligible nurses could work in ward or theatre based environments provided they were willing to discuss the causes of at least one IV MAE that they had been directly involved with.

Study contacts at each participating hospital distributed information about the study to nursing staff working on wards where IV medicines were administered frequently. Each interested nurse was given a study pack containing a letter of invitation, participant information leaflet and pre-interview questionnaire, and interviews were arranged once they returned the questionnaire to RNK. Participants were reassured that all outputs would be anonymised before providing written informed consent at each interview.

Data collection

Face-to-face semi structured interviews were conducted by RNK with each nurse participant in hospitals using the CIT.[16] A summary of the interview guide can be found in Box 1. The CIT has been used to collect empirical data on the causes of MEs[17,18] and explores problems by focusing on the intentions, behaviours and actions of those involved in specific situations, as opposed to estimations or generalisations.[16] These characteristics made the CIT a more useful data collection tool when compared with in depth interviewing, as it enabled high quality relevant data to be gathered from busy nursing staff.

An interview guide was constructed based on the principles of the CIT and previous work investigating PEs[17] with only minor typographical changes being made after piloting at one study site. Background demographic information was collected before participants were

asked to recall MAE(s) in detail (including nature and circumstances surrounding the MAE and perceived underlying causes). Nurses were invited to discuss both MAEs that reached the patient and errors that were caught and rectified before administration.

Categorisation of MAEs was based on established definitions,[4,9,11,19] with labelling errors considered as 'wrong preparation errors'. Interviews lasted between 26-60 minutes, were conducted in private rooms at each hospital and were audio recorded and transcribed verbatim.

Box 1: Summary of interview guide

Part One: Background

- Training background (including intravenous medication administration)
- Years qualified as a nurse
- Area of practice

Part Two: The intravenous medication administration error

- Error details (medication involved, error type, how was error discovered, did the error reach the patient)
- Circumstances at time of error (e.g. day of week, time of day, who else involved, location, physical/mental health, general workload, level of supervision, patient factors)
- Reasons for the error

Part Three: Reflecting on the error

- Changes to personal practice following the error
- Prevention of incident (what might have been put in place)

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Data analysis

Interview transcripts were coded and analysed using the NVivo© computer software program (v10) according to the Framework analysis approach.[20] Framework analysis has been used in applied social research since the 1980's to understand human behaviours, and has more recently found favour in healthcare research due to its rigorous, transparent and systematic approach to qualitative data management and analysis.[20,21]

Reason's model of accident causation was used to inform the generation of ~~a~~ themes within the Framework approach based on *a priori* knowledge [9] and emerging data from the interviews, and is summarised in Box 2 and Figure 1.[22,23] Data were coded as active failures and latent failures including error and violation provoking conditions and high level organisational decisions. The coding accuracy of each active failure was checked by a second author (SDW, JC and DMA), and the reliability of the coding framework was confirmed using 2 authors (SDW and JC) who independently extracted and analysed data for 10 interviews.

Ethical approval

The study was approved by the University of Manchester Research Ethics Committee (12028) and by the Research and Development departments of each participating NHS hospital trust.

Box 2: Reason's model of accident causation[22,23]

In this model accidents such as IV MAEs arise when defensive barriers which protect medication administration processes from subversion are compromised. This can result from the actions or omissions of those on the front lines (e.g. nurses), which are called active failures, as well as latent failures affecting the wider system in which they work. Latent failures arise primarily from decisions at a higher organisational level (e.g. hospital managers) which may be flawed, influenced by wider goals or limited by regulatory or financial constraints. These decisions can weaken defences whilst also influencing the working conditions of healthcare staff such as nurses to make them more hazardous, thereby creating error and violation provoking conditions (see Figure 1). Latent failures do not immediately lead to accidents; instead they lie dormant for long periods of time and may only be revealed when they combine with active failures in particular circumstances to cause accidents.

Active failures can be categorised at the operator level::

- Execution failures (plan is adequate to achieve outcome, but failure in execution):
  - Slips (observable actions and often associated with attention failures),
  - Lapses (internal events, often involving memory failure),
- Mistakes (plan is inadequate to achieve intended outcome, failures in problem solving):
  - Knowledge based (cannot use prior experience to solve a novel problem),
  - Rule based (misapply/omit a good rule or successfully apply a bad rule to solve a trained for problem), and
- Violations (intentional deviations from recommended practice (e.g. clinical procedures)).
  - Routine (e.g. cutting corners as habitual behaviour),
  - Optimizing (furthering personal rather task orientated goals),
  - Necessary (violation essential to perform task appropriately).

Although active failures may occur frequently their effects on defences are immediate and short lived; however the presence of any latent failures increases their frequency and the likelihood that their effects cause an accident such as an IV MAE to occur.

RESULTS

Twenty nurses were interviewed and 21 individual IV MAEs were discussed (see Table 1). The MAEs contained descriptions of 23 active failures, of which 8 were mistakes (5 knowledge based, 3 rule based), 7 were slips, 4 were lapses and 4 were deliberate violations of policy. Six different error and violation provoking conditions were identified: problems with the patient; the individual nurse; the task of drug administration; the healthcare team; the working environment and relevant equipment. Latent conditions were discussed as wider organisational decisions.

Table 1: Summary of study participants and reported IV MAEs

Participant code	Gender	Years since qualification[+]	Environment at time of MAE	Type of MAE	Did the error reach the patient	Medication class	Active failure(s)
N01	F	0-4	Ward	Wrong rate	Yes	Respiratory	Slip
N02	F	5-9	Ward	Wrong dose	Yes	Cardiovascular	KBM
N03	M	0-4	Ward	Wrong drug*[†]	Yes	Antimicrobial	Violation
N04	F	0-4	Ward	Wrong dose	Yes	Endocrine	Slip
N05	F	10+	Ward	Wrong rate	Yes	Electrolyte	Slip
N06	F	0-4	Ward	Wrong rate	Yes	Cardiovascular	KBM
N07	F	5-9	Ward	Wrong rate	Yes	Antimicrobial	KBM
		0-4	Ward	Wrong administration technique	Yes	Cardiovascular	Lapse
N08	F	0-4	Ward	Wrong drug[†]	Yes	Antimicrobial	Lapse
N09	F	0-4	Ward	Wrong rate	Yes	Respiratory	Slip
N10	F	0-4	Ward	Wrong dose*	No	Cardiovascular	KBM
N11	M	5-9	Ward	Wrong drug*[†]	Yes	Antimicrobial	Violation
N12	F	0-4	Theatre	Wrong preparation[Δ‡]	Yes	CNS	Violation (x2)
N13	M	10+	Ward	Wrong preparation	Yes	Antimicrobial	KBM
N14	F	10+	Ward	Unordered drug[Δ†]	Yes	Endocrine	Slip
N15	F	10+	Ward	Extra dose*[Δ†]	Yes	CNS	RBM
N16	F	0-4	Ward	Wrong rate	Yes	Antimicrobial	Slip
N17	F	10+	Ward	Wrong preparation[‡]	Yes	Cardiovascular	Lapse
N18	F	5-9	Ward	Wrong rate	Yes	Cardiovascular	RBM
N19	F	10+	Theatre	Wrong preparation[Δ‡]	Yes	CNS	Slip, RBM
N20	F	10+	Theatre	Wrong dose	Yes	Cardiovascular	Lapse

+ = Number of years after qualified/licensed as a nurse that IV MAE occurred
* = Indicates occasions where nurses prepared and/or administered prescribing errors (e.g. poorly written prescription)
† = Wrong drug, wrong patient, unordered drug and extra dose errors are considered 'unauthorised drug errors'
Δ = Indicates occasions where a complex chain of events involving different professional groups was involved
‡ = Indicates wrong label errors within wrong preparation group
Admin. = administration; CNS = central nervous system; F = female; IV = intravenous; KBM = knowledge based mistake; M = male; MAE = medication administration error; RBM = rule based mistake

Active failures

Casual attitudes toward dose checking were often discussed in relation to slips, whereas both types of execution failures shared common causal elements in equipment design (e.g. look-a-like medicines), distractions and familiarity with patients. One nurse reported how distractions adversely affected her when checking a pump infusion rate:

"[…] ward rounds going on […] the patients are buzzing and everyone's asking you for handover and they're wanting patients out the ward and all this to do and I think to be honest there was too much going on, and the fact that someone was standing talking to me just kind of like, took my attention away at the time." (N16, female, 0-4 years (qualified as a nurse when IV MAE occurred))

Knowledge based mistakes (KBMs) occurred when participants encountered novel or infrequent challenges and lacked sufficient knowledge, as one nurse described:

"[…] I didn't know that vancomycin given too quickly could cause that reaction [red man syndrome] at all. So you just…that's something else maybe my knowledge of that wasn't, kind of, good enough." (N07, female, 5-9 years)

When faced with knowledge gaps, nurses either lacked or chose not to access support resources due to a variety of reasons which included challenging professional relationships, high perceived workload and application of incorrect actions which were based on prior experiences.

Rule based mistakes (RBMs) occurred when nurses misapplied normally good rules regarding dosage adjustments for continuous infusions or for prescription checking activities. Infusion pump design, application of past experience, high perceived workload and local working practices were also implicated as contributory factors.

Most violations of procedures hinged on a decision not to challenge or question another member of the healthcare team when uncertain as to either the legibility of a prescription or

whether to administer a drug without it being checked. One nurse described how their knowledge of the condition being treated and their relationships with other staff members influenced the decision not to clarify an illegible prescription:

"[…] because of the clinical context I was like […] I know meningitis, I know ceftriaxone, […] and showing [the drug to] my peer and […] I trust that person implicitly. […] because I should've just said well, to the prescriber who wasn't there, […] would you re-prescribe this please, it's illegible. And you'd have to take grief off them […] And that is policy, that's what one should do. The problem with policy is that it doesn't take into the individuals accounts that the patient needs the antibiotic promptly. […] And it's a real balance, especially in the moment, in the clinical mind set what will take precedent." (N11, male, 5-9 years)

Error and violation provoking conditions

The patient.

The increase in workload and associated distractions which accompanied dealing with clinically deteriorating patients or their relatives either individually or collectively during busy shifts commonly contributed to slips and lapses. In some cases, workload pressures combined with nurses' concerns for other patients to adversely affect concentration on the task at hand leading to lapses and slips:

"[…] so I was probably rushing as well due to the stress of getting everything done on time, and with me having quite a poorly patient I really wanted to be focusing on him […] Because this patient, the lady, she was stable apart from the high potassium […] She was absolutely fine otherwise. So he was my priority, really." (N04, female, 0-4 years)

The individual nurse.

Participants described making KBMs or execution failures when they were not familiar with infrequently used medicines. Conversely, overconfidence when ascertaining the identity of prescriptions or checking infusion pump inputs or prescriptions also led to MAEs, and arose

due to familiarity with patients' treatment regimens, their physiological response to drug treatment or using infusion pump devices, as one nurse recalled when checking a prescription:

"[…] I didn't concentrate enough on the prescription […] I've known her for years she's been coming to the ward for years. I know exactly why she's coming in […] I had given her the drug myself [in the past] […] So somehow[…] I've allowed myself to see that [not concentrating] as acceptable." (N14, female, 10+ years)

Some newly qualified nurses described their lack of confidence and willingness to challenge others' decisions which contributed to IV MAEs. Perceptions of team hierarchy contributed to these decisions when nurses thought that doctors did not make mistakes or that they would inform them of important information personally (meaning they would not need to check the patient's medical notes). Others reported how they wanted to be perceived as managing their role but that in reality they struggled with workload, with two mentioning that fear of looking incompetent explained this behaviour. These opinions tended to change as the nurse grew in experience and felt confident to challenge others. Junior nurses in particular described how they had learnt bad practices experientially from more senior colleagues on the ward over time.

When dealing with multiple competing priorities and high workloads, nurses described reverting to a subconscious level of functioning which relied upon experiential pattern recognition often referred to as "autopilot" (N09, female, 0-4 years). Violations and execution errors resulted whilst in this state as decisions were made instantaneously and with little conscious thought of the circumstances at the time. Nurses also reported a task focused approach where IV administrations were rushed, particularly before lunch breaks, shift changes or between ward rounds, in order to focus attention on other tasks (e.g. poorly patients, other ward round duties) or reduce workload for others (e.g. on the next shift).

The healthcare team.

Illegible prescription and medical note documentation, prescribing using incorrect sections of the prescription chart and failing to record medication administration contributed to slips, mistakes and violations when nurses decided against or omitted looking at them or misinterpreted their meaning. Illegible documentation at times led some nurses to give higher importance to verbal communication with medical staff for patient care. However, verbal miscommunication also contributed to mistakes and lapses, particularly in noisy theatre environments.

Participants recognised that they did not check IV doses thoroughly if the prescription was written by a respected physician or the task was carried out with a trusted nursing colleague. The superior knowledge and confidence perceived to be held by more experienced nursing colleagues also contributed to junior staff accepting their decisions and not second-checking thoroughly, at times despite doubting the prescriptions' safety.

Nurses described how poor relationships with medical staff deterred them from clarifying ambiguous or possibly incorrect prescriptions; these perceptions were influenced by previous negative experiences of being pressured to administer, treated discourteously and not being understood. Perceptions of being beneath medical staff in the professional hierarchy were linked closely with these experiences. The positive patient safety contribution of pharmacists was often dependent on them being present on the ward when nurses needed them. Experiences of limited accessibility to pharmacists and/or doctors contributed to two violations, two mistakes and one lapse, when nurses either could not contact them or decided against doing so based on prior experience.

Risky practice norms contributed to MAEs and included dividing checking roles such that the medication was never checked by two people, preparing and administering multiple IV

medications simultaneously and, as one nurse described, administering all evening IV doses before shift change which pressurised her and promoted a task based approach to IV administration, leading eventually to a lapse:

"So being new myself it was drummed into me that we got the IV medications out before the night shift came on. So to me come eight o'clock, the night shift was starting […] So I felt pressure that I had to get them [IV doses] all out before they came out of the staff room [after shift hand over]." (N08, female, 0-4 years)

The working environment.

Noisy, chaotic and busy working environments pressurised and distracted nurses, leading them to rush tasks and fail to check prescriptions or dose preparation adequately. In one account, end of shift pressures combined with the ward layout and a temporary staff shortage encouraged a nurse to use time saving techniques when administering IV medicines on her own:

"[…] it was hand over period. One nurse went in to hand over and the other nurse was dealing with another patient in the bay and I was left to make up the IVs […] That's why I took them [medication trays] both together [for second checking] because it was the furthest away bay, so I thought to save time […] it was easier to get her to check them both […] Obviously not checking the things properly resulted in the error." (N08, female, 0-4 years)

Perceived high workload also contributed to mistakes and violations, and was increased due to temporary staff shortages, busy shifts, being responsible for more sick patients and inadequate staff skill mix. One nurse considered workload and other contextual factors when deciding whether to challenge an illegible prescription:

"[…] you'd be thinking, I need to get these medicines finished, because in an hour and a half's time, I've got my lunch time drugs to get out. So, that would have been a factor [in not clarifying an illegible prescription]." (N03, male, 0-4 years)

Interruptions and distractions contributed to a total of 11 IV MAEs, all but one (KBM) of which were execution failures. Participants described dividing their attention whilst conversing with patients, their relatives and other health care professionals. Distractions also originated from all other error and violation producing conditions.

Related equipment.

Ambiguous or obstructed dosage adjustment/checking interfaces on infusion pumps facilitated administration rate and dose errors via slips, mistakes and violations. In two cases, medicines required dose calculations which led to KBMs; in one account the medication vial was formulated for adults and the dose had to be converted for paediatric use. Look and sound-a-like medicines featured when nurses applied rules based on pattern recognition and consensus between colleagues or picked up the wrong product whilst distracted, as described below:

"[The medicines looked] absolutely similar, except for the writing [on the label] […] They were both in the same syringes." (N05, female, 10+ years)

The task.

The majority (n=17) of respondents described a failure in either their individual IV dose checking processes or the approach used when double checking with a nurse colleague as important contributors to IV MAEs. Weaknesses manifested as failures to read prescriptions properly, seek support, challenge prescribers and question the decisions of nursing colleagues, often despite personal doubts. A variety of other problems exposed the frailties of current IV dose checking practices which included individual overconfidence and distraction, patient illness severity, high workload and interruptions, intra- or inter professional relationships and inappropriate local working practices. One nurse described how some of

these error and violation provoking conditions influenced her when double checking IV doses for senior colleagues:

"[…] with the nature of the ward and it being so busy, I think it's becoming just a bit of a habit to people to just check the expiry date, check it's the right drug and then yeah, it's fine […] up until this incident I'd still say that if a sister asked me to check something, I would check it by the look of it […] she'll have done it right." (N04, female, 0-4 years)

Wider organisational decisions

Latent conditions were reported as a lack of availability of supportive resources for safe IV dosing such as drug reconstitution guidelines as well as insufficient access to medicines and other healthcare professionals during evenings and weekends. Logistical issues concerning the balance between new patient admissions and discharges and the timing of medication rounds also featured due to their negative effects on workload. Junior nurses mentioned that controlled access to IV administration as an undergraduate would have given them greater experience and confidence, thus preparing them more adequately for the demands of practice.

DISCUSSION

This study has found that hospital nurses' IV MAEs occur largely due to the error and violation provoking environment in which they work. Key strengths of this study are that it is the first to focus on investigating the causes of IV MAEs using interview based CIT to generate detailed error accounts, we achieved data saturation in the main emerging themes and that data analysis was carried out using human error theory which facilitated identification of a range of systems failures. Depending on which active failure a nurse made, different combinations of error and violation provoking conditions were responsible, though considerable overlap existed as latent failures were closely linked.

Implications of findings

Active failures and error and violation provoking conditions.

Execution failures most often occurred when nurses were working in familiar surroundings on routine tasks, but were either distracted or experienced changes in their immediate environment (e.g. emergencies)[23] which is consistent with the MAE literature which has studied these failures.[9,11,12,18] Unlike prescribing errors,[24] execution failures causing IV MAEs described by participants were often not identified and corrected before administration to patients.

KBMs had roots in lack of knowledge and experience of using medicines[9,11,12,17,18] but were also dependent upon the quality of checking processes and whether nurses were able or chose to access supportive resources. A recent review of interventions designed to reduce MAEs in hospitals reported that education, training and increased access to supportive resources generally showed positive results.[10]

Accounts of violations revealed insights into intra-and inter-professional relationships and how nurses made clinical judgements in practice. Others have also identified the risks posed by violations in leading toward MAEs[9,25] with this active failure appearing frequently in IV MAEs.[11,12,18]

The collective accounts of nurse participants reveal that a number of health care team and working environment related conditions contributed to multiple active failure types. Nurses were the inheritors of prescribing errors made by other team members leading to MAEs (mistakes and violations), findings which have also been acknowledged by others investigating the origins of related ADEs.[3] There is growing interest in the effect of interruptions and distractions on patient safety, and this study builds on previous work in associating them with MAEs.[9] Previous efforts to reduce the impact of interruptions whilst administering medication show little evidence for improvements in error rates[26] and nurses in this study also voiced mixed opinions towards these strategies. Attention now appears to be shifting towards understanding the origins and management of interruptions.[27,28] Future research could build on the principle that some interruptions contribute positively toward patient care and instead focus on empowering and training nurses in interruption management.[26-28]

Timing of medicines administration.

Timing dependent contextual influences were shaped by local working norms and the nurses' desire to improve patient care, and were crucial contributory factors to IV MAEs. At times, nurses rushed tasks, cut corners and worked subconsciously as they felt under pressure to administer IV doses. This pressure emerged from the need to attend concurrent ward rounds, to clear outstanding tasks for the next shift, to cover others' workload whilst they were in shift hand over, to meet the demands of medical staff or to respond to emergency situations.

Whilst efforts to improve shift hand over have shown positive results for medical errors,[29] no such interventions have yet been tested robustly for their effects on MAEs.[10]

Interestingly, workload was not mentioned as a contributory factor for the KBM and violation that occurred on weekends, and instead a lack of access or decision not to utilise supportive resources (medical and pharmacy staff) normally present during weekdays featured ~~most strongly~~. Few have sought to determine whether MAE or related outcomes are more prevalent on weekends.[30]

Checking processes.

Although inadequate checking processes have been reported previously as a contributory factor to error,[31-34] these factors do not feature strongly in previous investigations of IV MAE causes[9,11,12] or as a part of robust interventions designed to reduce MAEs.[10] Checking exercises failed when nurses assumed over-competence and trust in each other or medical staff, were distracted by other duties, approached the administration task over-confidently without checking or could not or decided against accessing additional support. Earlier research in nursing[33,34] and medicine[17] have acknowledged similar issues regarding over-reliance on colleagues.

Current UK nursing standards for medicines management state that all IV dose calculations should be independently checked and that where possible IV administrations should be checked by a second registrant (without specifying exactly when checking should take place).[35] In England, 85% of NHS hospitals have a double checking policy for IV doses.[36] The majority of nurses in this study were unsure or gave conflicting accounts as to what they perceived to be correct checking policy, perhaps indicating a lack of understanding of this process.[33] As the majority of dose calculation second checks in one UK paediatric hospital were not independent[32] and the effect of double checking more generally on MAE

rates in unclear,[31] a fundamental principle guiding remedial approaches should perhaps be to stress the importance of equal responsibility between two practitioners involved, and that nurses of any grade should be empowered to challenge others given the fallibility of human nature.[34]

Task management.

Nurses described how the working environment often resulted in management of tasks at a subconscious level using experience in order to manage their duties, as they perceived that they had little time to complete all their work or stop to think about what they were doing. Mental workload has received little attention in previous MAE research.[9,11,12,18] This led to some considering drug administration as a task of less importance when compared to other duties or overall shift goals, causing them to rush administration so they could move onto other duties. Others were rendered susceptible to inappropriate application of pattern recognition or missing important checking steps in maintaining safety whilst distracted.

Decision making by nurses during IV medication administration has been studied[37] as have the underlying theoretical principles behind such behaviours.[38] The findings of this study reflect the work of other researchers which suggests that we manage and process information using Type 1 (predominant approach, using intuitive subconscious responses based on instinct and repetitive experiences) and Type 2 thinking modes (conscious, analytic responses which are slower), both of which are prone to cognitive biases that can lead to error.[39] Nurse respondents shared beliefs with those from earlier work regarding how patient advocacy, a sense of time pressure and familiarity with their patients contributed to their decision making during administration.[37] However, as these decision making investigations predominantly tried to understand how nurses maintain safety during medication administration, further work could focus on understanding which cognitive biases negatively

affect medication safety for nurses, and how practitioners can recognise and minimise them in their own practice.

Limitations

Data collection relied upon nurses self-reporting and recounting past IV MAE events which increases the risk of recall and hindsight bias.[40] Social desirability bias[41] was minimised by using CIT as nurses were encouraged to explore their actual behaviours and describe circumstances at the time in detail. Nurses openly accepted blame for their errors and at times required prompting to reveal latent failures which could have reduced attributional bias.[42] Recruitment of participants from two NHS hospitals may have limited the representativeness of the findings to other health care settings.

CONCLUSION

This qualitative critical incident study has revealed the complex interactions between active and latent failures that underpin the emergence of IV MAEs in UK hospitals. Depending on the active failure made by front line staff, a number of a range of error and violation provoking conditions are often present. Three of these conditions were found to contribute to most identified MAEs: these were the dose checking activities carried out by nursing staff, the mental workload of nurses in order to manage the demands of their role, and the timing of ward based activities such as shift changes as well as the shift patterns of healthcare staff during weekends. This evidence suggests that a number of complex and multifaceted novel interventions may be required in order to reduce the burden of IV MAEs in hospitals.

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Competing interests

All the authors have no competing interests to declare. This work has not been posted or published elsewhere in its entirety with the exception of RNK's Doctor of Philosophy (PhD) thesis. An abstract summarising the study was presented at the European Drug Utilization Research Group (EuroDURG) Annual Scientific Meeting (August 2014, Groningen, The Netherlands).

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Contributions

Conception of study: all authors. Design of study: all authors. Participant recruitment: RNK, SDW. Data collection: RNK. Data transcription: RNK and authorised external transcribing company. Data extraction: RNK, SDW, JC. Analysis of data: RNK. Preparation of manuscript: RNK. Review and approval of manuscript: all authors.

Data sharing statement

No additional data available.

Figure legends

Figure 1: Reason's model of accident causation as applied to medication administration error research

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