Resilience in nursing medication administration practice: a systematic review with narrative synthesis

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ABSTRACT

Resilience in nursing medication administration practice: a systematic review with narrative synthesis.

Objective Little is known about how nurses adapt medication administration practices to preserve safety. The capacity to adapt and respond before harm occurs has been labelled 'resilience'. Current evidence examining medication safety largely focuses on errors and what goes wrong. This review aimed to synthesise evidence for the application of resilience principles and practices in nursing medication administration.

Design The Preferred Reporting Items for Systematic Reviews and Meta-Analyses guided the review, which was registered with PROSPERO.

Data sources MEDLINE, EMBASE, PsychINFO and CINAHL databases were searched from 14 August 2020 to 1 January 2021 for English-language studies.

Methods A systematic review of empirical studies of any design relating to resilience and safety in nursing medication administration in the inpatient setting was conducted. Methodological quality was appraised using the Mixed Methods Appraisal Tool. Data were synthesised thematically.

Results Thirty-two studies with a range of methodologies of mostly good quality met the inclusion criteria. Eleven interventional studies included two that evaluated the effectiveness of education interventions and nine exploratory studies with outcomes showing the impact of an intervention designed or examined to build resilience. Twenty-one non-interventional studies showed how resilience principles are put into practice. Only three studies explicitly named the concept of resilience. Resilient medication administration strategies result from five triggers.

Conclusions Nurses' resilience practices were found to be responses to identified trigers that threaten safety and productivity. These were often short term, real-time proactive adaptations to preserve safety, compensating for and responding to complexities in the modern healthcare setting.

PROSPERO registration number CRD42018087928.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Resilience is a source of patient safety through adaptation to the constant variations and changing risks to maintain care quality and safety. Adaptations represent 'work-as-done' describing what actually happens in response to environmental complexity, as opposed to the 'work-as-planned' captured in guidance and standard operating procedures.

⇒ A focus on how safety is routinely maintained (ie, successful compensatory practice), as opposed to what goes wrong, is an important area of study for nursing medication administration practice.

WHAT THIS STUDY ADDS

⇒ Our analysis aligns the often short-term, real-time adaptive practices during nursing medication administration with the theoretical concept of resilience and identifies the triggers for 'work as done'.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study strengthens conceptual and operational clarity for future research into nurses' capacity to adapt to dynamic risk to maintain safety in medication administration, paving the way for future interventions and strategies to promote resilience and patient safety.

INTRODUCTION

Worldwide, registered nurses are accountable for preserving patient safety,[1] including the safe use of medicines.[2] Despite widespread efforts to improve safety through large-scale research, policy and regulation,[3] it continues to be a global concern.[4] Medication administration is a key nursing function[5] accounting for 54.9% of medication errors[6] and taking between 11.8%[7] and 29.1%[8] of nurses' time.

The globally recognised framework for safe medication administration practice is the 'Five Rights' (5 R's), ensuring the right patient receives the right drug at the right dose, at the right time, via the right route; yet the 5 R's have received criticism for not acknowledging the human and systems factors inherent in medication administration.[9]

Traditionally safety is defined as absence of accidents and 'freedom from unacceptable risk', what is termed a 'safety-I' approach.[10] More recently the concept of safety has been developed to include 'safety-II'. Here, the focus is not just risk and error prevention

but on preservation of safety under varying conditions by adapting to anticipated and emerging risks, termed 'system resilience'.[10] It is important to understand and design systems and practices that are more resilient to these dynamic risks[11]; the nursing challenge being to promote, support and learn from responsive adaptations that maintain safety during medication administration. Everyday practice can be represented as 'work as done' reflecting the complex nature of clinical work, in contrast to 'work as planned or imagined' set out in policies and guidelines.[12]

Nurse's adaptive or compensatory practices can be a key source of resilience when they preserve safety[13]; so understanding how nurses adapt to create safety and how resilience principles and practices are applied during nursing medication administration are important areas for enquiry.

The review aims to synthesise evidence for the application of resilience principles and practices in nursing medication administration by answering two specific research questions; how might resilience principles be applied? and what is the evidence for the effectiveness of strategies linked to resilience principles in improving safety in nurses' medication administration? Interpretation of review findings is theoretically informed by two complementary frameworks. Holden *et al's*[14] Systems Engineering Initiative for Patient Safety (SEIPS) V.2.0 model, a human factor framework for understanding how care processes, individual and sociotechnical work shapes patient safety outcomes in resilient systems; and Aase *et al's*[15] framework examining resilience emerging from individuals (internal resources) and organisations (external resources).

METHODS
Design
A systematic review was conducted following Centre for Reviews and Dissemination[16] and PRISMA[17] reporting guidelines and checklist. The Synthesis Without meta-analysis (SWiM) reporting items were used for quantitative interventional studies using alternative synthesis methods.[18] The protocol was registered with PROSPERO.

Search methods
Initial scoping searches of Ovid Medline refined the search strategy. A faceted approach[19] with three facets, 'patient safety' (including resilience synonyms), 'nurse medication administration' and 'hospital inpatient', was utilised. A context-specific definition of resilience was applied to the search, where resilience refers to adaptive or compensatory behaviour to maintain safe administration of medication in the face of variations and dynamic risks. For eligibility criteria, see table 1.

Search strategy
Four databases were searched from 14 August 2020 to 1 January 2021 to find relevant studies published before 1 January 2021 in four databases: MEDLINE, EMBASE, PsychINFO and CINAHL. Boolean search terms were developed with assistance from a university subject librarian, the final strategy is shown in box 1.

Table 1 Eligibility criteria

Context	Include	Exclude
Population	Registered nurses, registered nursing associates	Nursing students, any other healthcare professionals
Context	Administration of any medication, secondary care setting, any inpatient hospital setting, simulation of inpatient setting	Studies of drug incompatibilities, studies that examine incident reporting, any primary care setting, outpatients, day clinics, community drop-in centres, individual psychological resilience, studies using secondary analysis of existing data unless conducted by the original study team
Study focus	Patient safety, resilience (the ability to adjust functioning prior to, during, or following changes and disturbances in nursing medication administration practices to maintain high quality care)	Studies only reporting prevalence, measurement and characteristics of errors, studies only reporting reliability (the consistent, safe administration of medication), studies where nursing medication administration was not the main focus of the research or where data relating to nursing medication administration could not be extracted from the results
Country	Any country worldwide	
Publication type	English language, peer-reviewed studies of any study design meeting definition of resilience	Systematic reviews, non-empirical grey literature, conceptual articles, letters, non-English language, PhD and conference abstracts, PhD theses

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Box 1 Example of search strategy (Ovid Medline)

(Patient safety or safety II or safety-II or safety 2 or (safety adj2 (culture or climate)) or (reliab$ or resilien$) or (human adj2 (factor$ or error$)) or (workaround$ or work around$ or work-around$ or circumvention or non-compliance or improvis$ or shortcut$ or double check$ or Safety Management/or Medication Errors/ or (error adj3 (detect$ or wisdom)).mp
AND
(((Nurs$ or Nursing) and ((medication$ or medicine$ or drug$ or dose or dosage or dosing) adj5 administration)).mp
AND
((in-patient$ or inpatient$ or acute or secondary care or hospital$ or Inpatient/ or Hospitals/)).mp

Study selection

Study identification was undertaken with two stages of inter-reviewer reliability, confirmation of full-text inclusion and quality assurance (see figure 1). A first-stage eligibility assessment of title and abstract by the primary author was confirmed for 5% of records with two reviewers confirming 2.5% each, with 97% agreement. A second stage title and abstract screen classified the records as empirical or non-empirical and confirmed the research focus with 95% confirmation of 5% of records with the reviewers. In both stages, unresolved records went through to full text review, an additional reviewer was not required. Further exclusions were made on subsequent examination of the full texts as some abstracts did not report sufficient detail, study type or focus. Final included studies were grouped according to whether or not they evaluated an intervention.

Quality appraisal

Concurrent quality appraisal used the Mixed Methods Appraisal Tool (MMAT),[20] appropriate for assessing a variety of methodologies and designs. No studies were excluded based on quality,[20] which was reported descriptively and confirmed by two reviewers for 30% of included studies.

Data extraction

Data were extracted and recorded using a bespoke tool developed through author piloting and review, displaying aspects of core details, study background and results. The detailed information is displayed in online supplemental files tables 1 and 2.

Synthesis of results

Meta-analysis of results across an extensive array of data was not possible due to heterogeneity in study outcomes and methodologies. Synthesis drew on the interpretive tradition, enabling maintenance of the rigour of the PRISMA and SWiM reporting guidelines and an iterative and dynamic approach to result synthesis. Data from result synthesis are provided (online supplemental table 2). A process of recurring theme identification grouped disparate data[21] using an iterative three-stage approach

of coding, descriptive themes and analytic themes.[22] This generated descriptive material to answer the first review question, and the analytic themes for the second. As part of the screening process, the included studies were differentiated by whether there was an interventional study design or not, but during result synthesis, this distinction became less discrete as the iterative themes evolved.

Patient and public involvement

As a PhD systematic review study, direct patient involvement in conduct of the research was not feasible. However, in initially proposing the topic, there was a keen awareness of the importance of the issues of medication safety and resilience in nurse medication administration practice for patients.[23] The systematic review forms the basis of a broader programme of work in this area by the authors, that is investigating how nurses adapt their administration practice to preserve patient safety, linked to two national research centres with medication safety research aims informed by patient advisory groups.

RESULTS

Identification of selected studies

The database search yielded 5416 records. Following screening, data were extracted from 32 studies. Identification of each stage of the search and selection process is summarised in the PRISMA diagram (figure 1).

Study characteristics

Included studies were published between 2005 and 2020 from five developed countries. The majority, 16 (50%) were conducted in the USA, with the remainder from Australia, 9 (28%), the Netherlands, 4 (13%), UK 2 (6%) and Norway, 1 (3%). Clinical specialities varied, with the majority, 22 studies (70%) in the adult setting, 8 (25%) in paediatrics, 1 (3%) was set in both adult and paediatric settings and 1 (3%) in a simulated clinical setting. Further study characteristics are outlined in online supplemental table 1. Although all studies cited core safety science literature related to resilience, only three studies explicitly referred to 'resilience' within the full text of their published articles.[13 24 25]

Study methods and quality of evidence

Study methods varied (see online supplemental table 1). Applying the MMAT's five categories of study design,[20] 22 (69%) studies had a qualitative design, 1 (3%) was a randomised controlled trial, 3 (9%) had quantitative non-randomised designs, 4 (12.5%) were quantitative descriptive and 2 (6%) were mixed method in design. The studies with qualitative designs often had more than one primary method of data collection, the majority using observational data, 7 (22%) or interview data, 6 (19%); and others using both observation and interviews, 4 (13%), focus groups, 3 (9%), and one study (3%) using observation, interview and focus groups; with another single study (3%) using focus groups and debriefs as primary methods to collect data. Quantitative non-randomised studies, 3
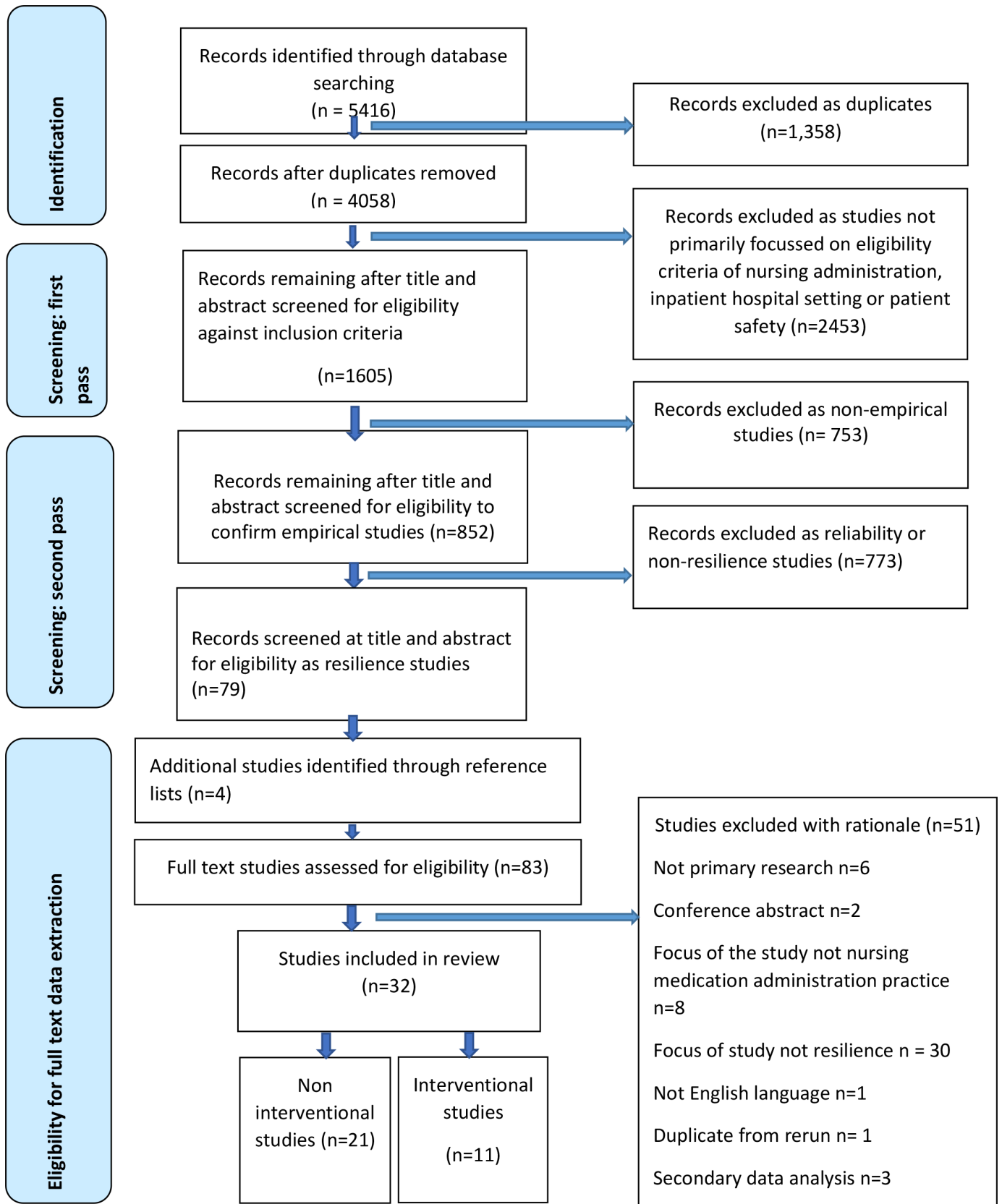
Figure 1 PRISMA flow chart. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

(9%) also used a variety of data collection techniques, including reports, 1 (3%), survey, 1 (3%) and observation with error reports, 1 (3%). The studies with a quantitative descriptive design mostly used surveys, 3 (9%) with one study (3%) using observation to gather data. The single randomised control trial was an experimental simulated

study using observation; and the mixed method studies both combined qualitative with quantitative descriptive approaches, with one using observation with participant narratives and the other combining focus groups and surveys to gather data.

Methodological quality is rated from the lowest quality 0, through 25, 50, 75–100, the highest quality. The majority of studies were rated high quality (online supplemental table 1). The lowest scoring design (in the quantitative non-randomised category) scored 25. All the other categories of study design were rated high quality scoring 75–100. Certainty of the evidence for the findings from the 11 evaluative studies is described as per study authors and the methodological quality tool.[20] Methodological quality was rated consistently high in the qualitative evaluative studies. For the four quantitative studies, this was more varied, with one of lower quality,[26] two studies of very good quality[27 28] and one of highest quality.[29]

Findings

Thematic analysis enabled linkage between practices and strategies, and theoretical principles of resilience resulting in five conceptual themes. Two practices—workarounds and double checking spanned two themes. The 11 interventional studies included 4 quantitative and 7 qualitative studies; online supplemental table 2 outlines their interventions, effectiveness measures and results. Study quality for the quantitative studies varied (online supplemental table 1); their metrics for outcomes being reported as provided by study authors due to heterogeneity in design. Three of the four studies, one RCT[28] and two non-randomised designs[26 29] evaluated the effectiveness of education interventions in respectively reducing interruptions and errors, improving scanning compliance and investigating the impact of work design on responses to missing medications. The fourth, a quantitative non-randomised study[27] assessed the impact of bar code medication administration on nurse's mental workload, their perceptions of safety and error likelihood. The remaining seven qualitative studies with interventions were of consistently high quality and were more exploratory in nature with outcomes showing the impact of an intervention designed to build resilience, or explore it's use.

1. Resilience as a response to the introduction of technologies in the workplace

Workarounds were often cited as being detrimental to patient safety, while eight studies illustrated workarounds where nurses adjusted their behaviour when interacting with technology in the interest of preserving safety. These studies explored a range of outcomes, resulting from the introduction of medication-related technology (online supplemental table 2) such as identifying nurses' use of an electronic medication management system with some suggested targeted interventions[30]; to documenting nurses' thinking processes[31] problem-solving behaviours,[24 32] perceptions of safety[27]; frequency or causes of workarounds[33]; or variability in practice[34] and

process problems.[35] Examples of resilience workarounds were nurses adapting technology-related protocols to ensure that a patient receives emergency medication for extremely low potassium[31] and responding to wristband failure, scanner or bar code on medication failures by workarounds to adjust the system.[33] Other workarounds involved technology process issues, such as programming an intravenous pump for extra volume to be administered to make sure all the medication is given,[32 34] nurses turning on the medication scanner in advance of use to account for slow booting or returning to paper-based records.[24] Here, nurses manually wrote down verbal medication orders, later following up with a call to physicians to issue an electronic version[35] or used paper-based records to 'mediate' the technology.[36] Contextual and human factors were found to play a role in perceptions of medication safety, linked by the 'fit' between the technology system and the nature of nurses' work[27] such as using the option in the barcode medication administration system to virtually extend a patient's hospitalisation to ensure analgesics can be administered to a patient in pain.[37]

2. Resilience enhanced by education

Three nurse education programmes operationalising theoretical resilience principles were found (online supplemental table 2). The first study[38] described a medication safety programme aimed at increasing sensitivity to error risk and reduce medication administration errors, including case studies, simulation, meditation and a checklist. The second study introduced safety measures including lit lanyards, making the medication room a No Interruption Zone, and using the electronic medication record during handover to reduce interruptions.[26] The third study, a nursing leadership initiative, refined a scanning reporting system and educated nurses about their scanning habits to increase compliance with medication scanning.[29] Two of the education programmes reported only short-term (less than 3 months) reductions in medication errors.[26 38] The first found an overall reduction in errors of 0.23% (p<0.003) of total number of medications administered per day[38]; the second found that errors reduced by 28 incidents over 3 months, compared with the same timeframe the previous year.[26] The third reported improvements in medication scanning compliance and other nursing safety practices, for example, identifying and correcting technical problems and making changes in clinical workflow to ensure patients receive timely medication prior to physiotherapy.[29]

3. Resilience through critical thinking and problem-solving

The literature demonstrated resilience through nurse's critical thinking in response to a range of triggers. Decision-making was tested in a simulated setting[28] in response to two operational failures: missing medication from the medication cabinet and lack of insulin syringes. Here, nurses were found to choose a safer policy-compliant workaround rather than an unsafe one

(using a syringe not designed for insulin) only when they had access to a manager and when given the right work design (closeness to pharmacy to get the missing supplies). Under these conditions, nurses also contributed improvement ideas to enhance the future resilience of the system.[28] Constant professional vigilance was found to remain unchanged after barcode implementation,[31] however the introduction of technology did result in new problem-solving behaviours. Here, a nurse used manual selection rather than the tethered scanner to identify a patient who was too far away to scan, and collaborated with a pharmacist to modify an 'immediate' prescription when the ordered dose of 20 mg was only available in two 10 mg doses, which they were unable to document as such on the system.[27] In exploring perceptions of safety, it was found that rather than their mental effort, nurses perceived it was how they reacted to external pressures such as feeling rushed, which impacted safety.[27]

Problem-solving workarounds (violations and/or adaptions to policy) during medication administration were reported in two studies.[39 40] When the reality of the environment was not matched by policy assumptions of the environment,[39] the intention to violate was influenced by the step of the administration process and triggered by whether it was a routine or emergency situation. Increased use of workarounds was linked to emotional exhaustion, but satisfaction with the administration system could exacerbate or reduce workarounds.[40]

4. Responding to distractions and interruptions

Study authors in seven studies identified an array of theoretical principles of resilience in response to distraction and interruptions. These included 'prioritisation' to address more urgent need,[25 41] 'blocking' to stop the interruption or 'engagement' with it,[42 43] 'prevention' of any potential interruptions,[42 44] 'multitasking'[43] and 'mediating' by asking colleague to intervene.[43] Nurses have also been found to generate 'personal safety systems' such as using sticky notes or marking on paper medication cups to maintain safety when interrupted or facing compelling work demands.[36] In an attempt to avoid distractions on a busy unit, nurses found a quiet space to prepare medications before administration.[45] Those nurses who were more 'task focused' tended to minimise interruptions and distractions[44] by putting up a screen at the entrance of the clinical area. For predictable interruptions, found nurses used preventive strategies such as timing their medication rounds to avoid ward rounds or taking patients to the toilet prior to medication rounds.[42] In unpredictable (usually emergency) situations, nurses most often used the strategy of 'engagement' with the interruption by prioritising it. This was usually to avoid compromising wider patient safety, for example, when a colleague asks for help with a baby having difficulty breathing.[42]

5. Responding to uncertainty or novel situations

When responding to uncertainty or novel situations, three subthemes were identified.

Augmenting decisions

This was used to preserve safety where nurses gave greater attention to medications perceived as higher risk, for example, insulin and chemotherapy,[13 46] and when handling time pressure by clustering medications prescribed for 8:00 or 10:00 by giving them together at 9:00 to facilitate timely administration.[47] Nurses used a smartphone light to check medication expiry dates in dimly lit areas, and an alarm reminder on their phone to ensure safety and timely medication administration.[2] Nurses were influenced by professional knowledge and patient data to 'tinker' and 'tailor' medication to individual patient need[48]; and decisions to alter prescribed timings in response to the individual's need for pain relief[37] or showing patients the medication chart to confirm that medications were appropriate[49] are resilient practices supporting safety.

Enhancing communication

Communication strategies to preserve safety included initiating and querying medication orders,[50] suggesting new medication along with the use of declarative language and closed questions,[51] using open communication and verification, such as asking 'is this what you want?' to gain clarity,[45] and scanning the medication administration record during an informal verbal handover.[52] There was some nuance between communication and double checking subthemes.

Double checking

As a resilient practice (performance of additional checks to those required by policy) is context specific and serves to maintain safety. Examples are nurses asking colleagues to double check[25] or even triple check medication not routinely used,[41] inviting patients to verify medicines[44] or deciding to do another check of the patient and the drug[53] to alleviate uncertainty and promote safety.

6. Reported changes and suggestions for improvement

The included studies made various suggestions for change and future practice, signposting strategies supporting safety-II thinking themed as environment, resources and professional development. Within the worked environment future suggestions included roll out of a piloted safety programme,[38] using a medication safety care bundle to reduce interruptions,[26] ensuring technology reflects nurse's tasks or context or usage,[27 32 34 35] system redesign to support safety[39] and superusers to provide support.[40] Resource-focused recommendations were changes to design and usability of medication administration technology,[24 27] increasing the availability of technology[30] and staff[30 46]; stressing the importance of both understanding the complexity of medication administration,[2 36 47] and the impact of policy on clinical judgement, to the organisation.[53] Suggestions for nurse professional

development centred on role modelling,[30] communication,[52] including understanding of professional role and identities,[51] enhancing insight recognising that safety extends beyond rules and procedure requiring critical thinking and judgement as part of professional expertise[25 26 31 45 48 49]; and education initiatives.[13 28 29 33 37 41–44 50]

DISCUSSION

This review aimed to answer two questions on the application of resilience practice in nursing medication administration—how might resilience principles be applied, and how effective are they in improving safety? Despite limited direct use of the concept of resilience in medication administration literature, this review has described and linked adaptive clinical practices ('work-as done') to resilience. Assessing effectiveness of resilience adaptive practices was only possible when this was an identified outcome measure, such as for educational interventions.

Evidence for the effectiveness of resilience strategies

Two intervention themes identifying external resilience (technology and education) and internal resilience (critical thinking) acknowledge the application of a resilience framework.[15] Findings sensitive to interventions included identifying barriers to the use and acceptance of technology, measuring sensitivity to error risk and improving error rates, perceptions of safety and changes in problem-solving behaviours. Clear outcome and effectiveness measures in terms of safety were less clear, but they did generate understanding and findings relevant to safety in nurse medication administration. It is suggested that resilience is not tied to measures or estimates of probability of adverse events[54] and this was found to be the case in this examination of the effectiveness of resilience strategies. Only one study directly addressed resilience as a response to operational failure, demonstrating nurses' capacity to adapt.[28] Two education strategies had short-term effects on error reduction[26 38] but longer term follow-up would have further supported the significance of these studies. The impact of technology on nurses' operational practice during medication administration warrants further exploration particularly regarding the necessity for workarounds, which demonstrate that some current configurations of technology/work system design are cumbersome and could be better optimised to support the human work of nurses.

'Workarounds' as resilience strategies

This review found examples of workarounds as either a response to working with technology or a response triggered by a situational context involving optimising decisions or critical thinking. Workarounds were interpreted by review authors as demonstrations of resilient solutions that promote safety, compensating for risks in the complex or unwieldy systems in which nurses administer medication. An alternative view sees workarounds as detrimental to patient safety, a source of risk and unstandardised variation. Insights from this analysis show workarounds are innovative, compensatory behaviours triggered by context and have a role in preserving safety.

Interpretation of resilience in the work system

The findings of this review identify resilient practices, which serve to control the environment when responding to complexity and suggests nurses make choices in their adaptive practices depending on the context and triggers. For example, by blocking (ignoring) an interruption, nurses chose to prioritise administering medication. Yet most of the time nurses engaged with interruptions, stopping the primary task of medication administration.[43] This is considered to be an adaptive strategy that may support a broader system resilience by accepting a reduction in the quality of medication administration. Significantly, the application of aspects from the SEIPS V.2.0 model[14] allowed description of the application of resilience practices (when either anticipated or unanticipated) as largely reactive, short-lasting intermittent adaptations; consistent with the work of Tucker and Edmondson[55] and similar to Hollnagel *et al*'s[56] 'find and fix' solutions to operational problems. An implication of the short time frame for these practices is that resilience is not stabilised and integrated in everyday work over time, and this misses the opportunity to achieve a planned, consistent, and high reliability environment. This has consequences for the safety of nursing medication administration. Findings from the studies in the review also highlight that adaptations can occur when available standardised protocols do not match the reality of clinical work. These variations in practice can be seen as vehicles for maintaining safety.[13 39] Greater clarity and understanding of resilient medication administration practices have shown that they are often short-term, real-time adaptations to preserve safety, compensating for, and responding to, the complexities of working in the modern healthcare setting.

The resilient practices identified in this paper show how nurses respond to the need to manage. Their ability to adapt, anticipate and learn has clear implications for an alternative view of nurses' safety strategies where the nurse is proactive in safeguarding the system, described as the nurse being the 'Hero', rather than the 'Hazard'.[57] This aligns with safety-II thinking, with its focus on how safety and reliability are routinely maintained. This review has explored the nuance of how resilience in the medication administration context is defined, and the paper has identified a need for a stronger conceptual basis for intervention and evaluation in this area. Using suggestions from the resilience in healthcare programme,[58] an outcome from this review proposes the following definition of resilience in nursing medication administration for future research in this area:

'Physical or mental compensatory or adaptive practices responding to detection of risks to patient safety before, during or after the process of administering medications to patients, where the nurse changes or

deviates from the planned model of work with the purpose of maintaining safety'.

Strengths and limitations

This review provides a comprehensive synthesis of the available evidence exploring resilient strategies in nursing medication administration. A major limitation was the lack of a standard definition of resilience as it applied to the context of nursing medication administration, with the possibility that with a broad concept like resilience, the search was not sensitive to all related work despite the application of a well-tested search strategy.

As encountered in this study, the broad heterogeneity in research focus and methods, differences in timeframes, scope of practice, technologies and policies across international data, pose challenges in terms of the practicality of a common conceptual framework for nursing resilience practice. However, it was possible to develop, through narrative synthesis, common themes in terms of broad resilience strategies and areas for improvement. Although the findings from the two large-scale studies set in the UK inpatient setting[13 44] appear to confirm similarities in the application of resilient strategies, earlier research does not describe resilient behaviour per se, no doubt due to the relatively recent uptake of the concept in the patient safety and health services research literature. As such, findings of this review should be interpreted in light of the difficulties of post hoc application of the concept of resilience where it was not an explicit focus of the original study authors and lack of prior intention for identified practices, not always possible to infer, but a necessary part of describing the evidence.

Future research

Further alignment of resilient practices arising from medication administration with current thinking regarding the strengths of a safety-II approach and examining the tension between professional accountability and resilience are important to understand.

Future research might productively build on these review findings to better establish the concept of resilience and its application in administration practice. Exploring linked notions such as 'work as done' alongside policy ('work as imagined') is needed to support the design, evaluation and reporting of interventions that contribute to wider organisational safety.[12]

Once applied frameworks for resilience in this setting are in place, there is a need to establish the effectiveness of resilience strategies in medication administration on patient safety with robust interventional designs, clear outcome measures relating to safety improvement; and outcome measures that better represent resilience in the system in terms of nurses' capacity to adapt. Further understanding of how resilience is achieved and how it can be sustained is key to developing resilient healthcare. This could be supported by research to suggest ways to translate temporary resilience strategies into reliable error recovery 'safety nets' over time, potentially leading to improved medication administration safety.

CONCLUSION

This review set out to explore resilience in the context of nursing medication administration. Developing the understanding of how medication practices align with contemporary safety science theory has enabled description of the ways in which nurses exhibit resilient behaviours to maintain system safety in response to a number of contextual and environmental triggers that have been classified. These findings have implications for practice, policy and research and will strengthen conceptual and operational clarity by guiding the design, evaluation and reporting of interventions for supporting nurses' capacity to adapt to dynamic risks in the complex systems in which they work.

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Table 1 (Supplementary file) Characteristics of data collection, study design and methodological quality score using Mixed Method Appraisal Tool research categories and methodological quality criteria for all included studies in hospital inpatient settings.

1st author (year)	country of origin	Population	study aim	primary method(s) of data collection	*Primary category of study design [secondary category]	**Tool score
Studies with an intervention						
Debono *et al.*, (2017)(30)	Australia	Adult	To identify perceived barriers and targeted interventions to enhance appropriate use of electronic medication management systems.	Interviews	Qualitative Study [Qualitative description]	100
Durham *et al.*, (2016)(38)	USA	Adult	To increase nurse sensitivity to potential error risk, improve behaviours, and reduce observed medication administration errors.	Observation	Qualitative Study [Process improvement]	100
Eisenhauer *et al.*, (2007)(31)	USA	Adult	To document nurses' reported thinking processes during medication administration before and after implementation of point-of-care technology.	Interviews	Qualitative Study [Narrative research]	100
Freeman *et al.*, (2013)(26)	USA	Adult	To reduce the number of interruptions during medication administration.	Observation and error report	Quantitative non-randomised study [Before and after time series study]	25
Holden *et al.*, (2013)(24)	USA	paediatrics	To investigate how barcode medication administration alters nursing work, and the nature of problem-solving behaviour following its implementation.	Observation and interviews	Qualitative Study [Qualitative description]	100
Holden *et al.*, (2015)(27)	USA	paediatrics	To assess the short- and long-term impact of bar-coded medication administration on nurses' mental	Survey	Quantitative non-randomised study [Before and after time series study]	75

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1st author (year)	country of origin	Population	study aim	primary method(s) of data collection	*Primary category of study design [secondary category]	**Tool score
			workload as well as on perceived medication safety.			
McAlearney *et al.*, (2007)(32)	USA	Adult	To explore nurses understanding of introduction and use of smart pumps	Focus groups	Qualitative Study [Qualitative description]	100
Nemeth *et al.*, (2014)(34)	USA	adult medical & surgical	To evaluate the use of an infusion device among nurses.	Observation and interview	Qualitative Study [Ethnography]	100
Niazkhani *et al.*, (2011)(35)	Netherlands	adult	To evaluate the problems and responses after introduction of computerized physician order entry system.	Interviews	Qualitative Study [Qualitative description]	75
Tucker, (2016)(28)	USA	simulation lab	To investigate the impact of work design factors on responses to operational failures.	Observation	Quantitative Randomised Control Trial [Quantitative Randomised Control Trial]	75
Van Ornum, (2018)(29)	USA	Adult	To improve barcode medication administration compliance.	Medication scanning reports	Quantitative non-randomised Study [Cross-sectional analytic study]	100
Non-interventional studies						
Boonen *et al.*, (2017)(48)	Netherlands	adult	To explore the impact of nursing practice when working with bar-coded medication administration technology	Institutional ethnography Observation	Qualitative Study [Ethnography]	100

1st author (year)	country of origin	Population	study aim	primary method(s) of data collection	*Primary category of study design [secondary category]	**Tool score
Boonen *et al.*, (2018)(37)	Netherlands	adult	To assess how care is mediated through technology by analysing the interaction between nurses, patients, and a Bar Coded Medication Administration system.	Institutional ethnography Observation	Qualitative Study [Ethnography]	75
Boonen *et al.*, (2020)(36)	Netherlands	adult	To determine how, from a standpoint of nurses, the use of bar-coded medication technology institutionally and textually mediates nurses' deliberations in the process of decision-making.	Institutional ethnography Observation	Qualitative Study [Ethnography]	75
Borrott *et al.*, (2017)(51)	Australia	paediatrics	To examine how communication between nurses and doctors occurred for managing medications.	Interview, observation, focus group	Qualitative Study [Ethnography]	100
Jennings *et al.*, (2011)(47)	USA	adult	To describe medication administration and managing strategies in everyday clinical practice.	Observation & interview	Qualitative Study [Ethnography]	75
Aydon *et al.*, (2016)(50)	Australia	paediatrics neonatal ICU	To identify factors that influence nurse's decisions to question concerning aspects of medication administration.	Interview	Qualitative Study [Qualitative description]	100
Dickson & Flynn (2012)(45)	USA	adult medical & surgical	To explore nurses' clinical reasoning and actions to intercept medication errors	Interview	Qualitative Study [Grounded theory]	100

1st author (year)	country of origin	Population	study aim	primary method(s) of data collection	*Primary category of study design [secondary category]	**Tool score
Braaf *et al.*, (2015)(52)	Australia	adult	To investigate what and how medication information is communicated during handover interactions.	Observation	Qualitative Study [Qualitative description]	100
Colligan & Bass., (2012)(41)	USA	paediatrics	To identify types of interruptions and strategies for safe medication administration and interruption management.,	Semi-structured interview	Qualitative Study [Qualitative description]	75
Davis *et al.*, (2005)(46)	Australia	paediatrics	To identify nurses' attitudes toward medication policies and perceived factors influencing nurses' adherence to the medication policy	Focus group	Qualitative Study [Qualitative description]	100
Johnson *et al.*, (2018)(42)	Australia	adult	To examine the nature of interruptions during medication administration.	Focus group	Qualitative Study [Qualitative description]	100
Martyn & Paliadelis (2019)(49)	Australia	adult	To explore nurses' medication administration experiences.	Observation & interviews	Qualitative Study [Qualitative description]	100
Sitterding *et al.*, (2014)(43)	USA	adult acute	To describe situational awareness during medication administration, and interruption handling strategies.	Observation	Qualitative Study [Qualitative description]	100
Vos *et al.*, (2020)(13)	England	mixed: adult & paediatric	To explore ways in which nurses contribute to system-level resilience when administering intravenous infusions.	Focus groups & debriefs	Qualitative Study [Qualitative description]	100

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1st author (year)	country of origin	Population	study aim	primary method(s) of data collection	*Primary category of study design [secondary category]	**Tool score
Martyn & Paliadelis (2019)(2)	Australia	adult	To explore the participants' application of the five-rights of medication administration in practice.	Observation	Qualitative Study [Qualitative description]	100
Alper *et al.*, (2012)(39)	USA	paediatrics	To assess the extent of violations in the medication administration process among nurses.	Cross-sectional survey	Quantitative descriptive Study [Survey]	100
Davis *et al.*, (2010)(53)	Australia	paediatrics	To evaluate the importance of contextual and policy factors on nurses' judgement about medication administration practice.	Cross-sectional survey	Quantitative descriptive Study [Survey]	100
Halbesleben *et al.*, (2013)(40)	USA	adult	To examine relationships between emotional exhaustion and potentially unsafe work practices (workarounds) in medication administration.	Survey	Quantitative descriptive Study [Survey]	100
Alteren *et al.*, (2018)(25)	Norway	adult	To describe nurses' behaviours and interruptions during medication administration.	Observation	Quantitative descriptive Study [Incidence or prevalence study without comparison group]	75
McLeod *et al.*, (2015)(44)	UK	adult	To identify system factors that facilitate and/or hinder successful medication administration focused on three inter-related areas: nurse practices and workarounds, workflow, and interruptions and distractions.	Observation & participant narratives	Mixed methods [Qualitative & Quantitative descriptive]	100
Rack *et al.*, (2012)(33)	USA	adult medical & surgical	To determine the existence, frequency, and potential causes of nursing workarounds, and error reduction, when implementing a bar code medication administration system.	Focus group and survey	Mixed methods [Qualitative & Quantitative descriptive]	75

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*Mixed Methods Appraisal Tool study design categories: Qualitative; Quantitative randomised controlled trials; Quantitative non-randomised; Quantitative descriptive; Mixed methods. ** Mixed Methods Appraisal Tool score: 0, 25, 50, 75 or 100 where 0= poor quality, 100 = high quality

Table 2 (Supplementary file) Resilience interventions, effectiveness measures and results.

Author (year)	Intervention [intervention type]	Study target outcomes	Relevant resilience findings/results with examples
Debono *et al.,* (2017)(30)	Electronic medication management system [Technology]	1) Identification of nurses' use of electronic medication management systems in everyday practice 2) perceived barriers to appropriate use of electronic medication management systems using TDF*	Barriers to technology use were represented in 9 TDF domains. The major barriers were in domains 1 and 2: **Domain 1** societal/professional role and identity, e.g. at night to avoid waking patients, nurse did not take computer on wheels to bedside **Domain 2** environmental context and resources e.g. When nurses judged that taking the computer on wheels into a room created a falls or infection risk, they left it outside.
Durham *et al.,* (2016)(38)	Medication safety programme [Education]	1) the frequency of error interception practices 2) reduction in medication administration errors	Immediately post-programme, 99% of 99 nurses agreed their awareness of potential error risk increased. 10 weeks post-programme, error interception practices increased by 92% in the acute unit and by 303% in intensive care unit; 61% of respondents were using brief breath mindfulness meditative exercise to gain situational awareness. The programme effect was significant if route errors are removed from the analysis. Observed medication errors decreased.
Eisenhauer *et al.,* (2007)(31)	Bar code medication administration and electronic medication [Technology]	1) Documentation of nurses' reported thinking processes 2) effect on practice during medication administration	10 descriptive categories of nurses' thinking were identified including workarounds, anticipating problem-solving, assessment and evaluation. For example, workarounds included working around technology-related protocols to ensure a patient receives emergency medication. Anticipatory problem-solving included starting with a lower dose to enable assessment of patient's response to the dose before increasing. Most nurses' reported thinking did not change after the implementation of technology, except for the different types of checking it introduced.
Freeman *et al.,* (2013)(26)	Bundle of safety measures (e.g. no interruption zone, phone call /pager triage, patient / family / MDT education, staff	1) Reduction in interruptions during medication administration 2) reduction in reported medication errors	Number of interruptions reduced by 2.11 per medication encounter. Reported total errors reduced by 28 incidents over 3 months when compared with the same period in the previous year. Anecdotal feedback indicated the medication room was much quieter post-implementation and nurses placed more importance on the process of medication administration which assisted to reduce interruptions.

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Author (year)	Intervention [intervention type]	Study target outcomes	Relevant resilience findings/results with examples
	rounding, response to alarms) [Education]		
Holden *et al.,* (2013)(24)	Barcode medication administration technology [Technology]	The nature of new problem-solving behaviours	3 themes of new problem-solving behaviours: 1) invention of new problem-solving behaviour e.g. electronically sorting medications by name before printing, to enable quick access to that information by making a paper administration schedule. 2) intervention of technology blocked familiar problem-solving behaviour e.g. nurse collaborated with pharmacist to create 2 new orders (for 2 x 10mg of a drug) when a 20 mg dose not available. 3) technology created new problems, only some of which nurses were able to solve using familiar or novel problem-solving behaviours. e.g. turning on scanner in advance to account for slow booting.
Holden *et al.,* (2015)(27)	Barcode medication administration technology [Technology]	Changes in perceptions of safety, error likelihood and mental workload	Confirmation of hypothesis that external workload (interruptions, divided attention and being rushed), but not internal mental workload (concentration, mental effort) was associated with the perceived likelihood of a medication safety event. Perceived likelihood of medication errors decreased in one clinical area following the intervention. Nurses' perception was that how they reacted to external pressures, such as feeling rushed, had a perceived impact on safety.
McAlearney *et al.,* (2007)(32)	Smart IV pumps with decision support [Technology]	Improvements in understanding and challenges of additional decision support with smart pumps.	Challenges to smart pumps identified and nurses' workarounds in response to challenges identified, such as programming pump for extra volume to be administered to make sure all drug is given; using different modes to allow infusion of medications not listed in pump library.
Nemeth *et al.,* (2014)(34)	Smart IV pumps with decision support [Technology]	Desirable and unforeseen outcomes of implementation of smart IV pumps	Nurse-pump interaction and pump interface variability created both desirable and unforeseen outcomes. Workarounds are used to cope with mismatch between smart infusion design and actual care requirements. Such as working around the pump options when prescribed drug was not programmed into drug library, so nurse enters more or less than the amount indicated on the bag.
Niazkhani *et al.*, (2011)(35)	Computer physician order entry [Technology]	Medication-use process problems and workarounds	Some workarounds either eased or accelerated performance of tasks that support safety e.g. double checking for clarification of online orders, writing down verbal orders in records or notes

Author (year)	Intervention [intervention type]	Study target outcomes	Relevant resilience findings/results with examples
			and following up with a call to physicians to issue an electronic version, asking patients to bring in home medications
Tucker (2016)(28)	Impact of work design factors on responses to operational failures [Critical thinking]	Responses to operational failures (missing medications) including 1) speaking up about the operational failure 2) contribution of a written improvement idea and 2) engagement in policy compliant workarounds	Nurses engaged in policy compliant workarounds only when it was easy to do so, but they are more likely to use the policy compliant workaround when they have high access to the process owner; otherwise, they used non-policy compliant workarounds. The inconvenience of the operational problem is what motivates them to contribute an improvement idea.
Van Ornum, (2018)(29)	Leadership initiative [Education]	Nurses' medication scanning compliance	Improvement in medication scanning compliance from 95% to 98% of medications. Nurses identified technical problems, quickly corrected these and made changes in clinical workflow and communication to ensure medication administered in a timely fashion.

*TDF: Theoretical Domains Framework