Current Issue

Volume 3 Issue 1

APRIL 2017
ISSN: 2204-9762

Previous Article Next Articl

ORIGINAL ARTICLE

An observational study of nurses' intravenous flush and medication practice in the clinical setting

Author(s): Samantha Keogh RN, PhD*
School of Nursing and Institute of Health and Biomedical Innovation (IHBI), Queensland University of Technology (QUT), Qld, Australia
Alliance for Vascular Access Teaching and Research Group (AVATAR), Menzies Health Institute Queensland (MHIQ), Griffith University, Qld, Australia
Nursing and Midwifery Research Centre, Royal Brisbane and Women's Hospital, Qld, Australia

Caroline Shelverton RN, BN
Alliance for Vascular Access Teaching and Research Group (AVATAR), Menzies Health Institute Queensland (MHIQ), Griffith University, Qld, Australia
Nursing and Midwifery Research Centre, Royal Brisbane and Women's Hospital, Qld, Australia

Julie Flynn RN, MAdvPract
Alliance for Vascular Access Teaching and Research Group (AVATAR), Menzies Health Institute Queensland (MHIQ), Griffith University, Qld, Australia
Nursing and Midwifery Research Centre, Royal Brisbane and Women's Hospital, Qld, Australia

Karen Davies RN, BN
Nursing and Midwifery Research Centre, Royal Brisbane and Women's Hospital, Qld, Australia
School of Pharmacy, University of Queensland, Qld, Australia

Nicole Marsh RN, MAdvPract
Alliance for Vascular Access Teaching and Research Group (AVATAR), Menzies Health Institute Queensland (MHIQ), Griffith University, Qld, Australia
Nursing and Midwifery Research Centre, Royal Brisbane and Women's Hospital, Qld, Australia

Claire M Rickard RN, PhD2,3
Alliance for Vascular Access Teaching and Research Group (AVATAR), Menzies Health Institute Queensland (MHIQ), Griffith University, Qld, Australia
Nursing and Midwifery Research Centre, Royal Brisbane and Women's Hospital, Qld, Australia

* Corresponding author
Professor Samantha Keogh, School of Nursing, Queensland University of Technology, Victoria Park Road, Kelvin Grove, Brisbane, Qld 4059, Australia
s2.keogh@qut.edu.au

Pages 3-10

ACKNOWLEDGEMENTS

The researchers wish to thank the staff who participated in this study for their time and cooperation. The researchers also wish to acknowledge BD Medical for their support for the study through an unrestricted grant-in-aid. However, BD did not contribute to the study protocol or have access to the study data, analysis, or final results prior to submission of the report. Nor did BD have any input into the manuscript.

DISCLOSURES

Through the respective employer each author has received unrestricted donations, investigator-initiated research grants or in-kind support on their behalf for projects unrelated to this research from flushing product suppliers (BD, Baxter and/or BBraun). SK, CR, and NM's employer has received funding on their behalf for commercial consultancies (educational lectures, opinion and one research project) from commercial suppliers of flushing products (BBraun and BD).

INTRODUCTION

Research has quantified the unacceptably high failure rate of peripheral intravenous catheters (PIVCs) prior to completion of prescribed treatment for reasons including: infection, phlebitis, infiltration, occlusion and dislodgement. Failure due to occlusion, infiltration, dislodgement or phlebitis currently ranges from 26%–44% locally[1-3] and 23%–100% worldwide[4-9]. Researchers and policy makers require a better understanding of PIVC maintenance practice to identify contributing factors in order to design, test and implement interventions to reduce failure. Reducing the overall PIVC failure rate by just 10% would equate to a saving of $140 million nationally each year, in addition to improving service delivery, by reducing interruptions to patient therapy and painful procedures related to replacement of PIVCs[10-12].

BACKGROUND

Flushing is a historical practice with a poor evidence base, and current flushing practices vary widely[13]. Recent participation in a worldwide point prevalence study related to PIVCs, conducted by members of our research team, identified that there was large variation in flushing policies and practices[14]. In addition, the uptake of innovative healthcare technologies was variable and poorly understood. The purpose of flushing is to maintain catheter patency by preventing internal luminal occlusion, theoretically by reducing build-up of blood and other products from the PIVC internal surface, and by prevention of interactions due to incompatible fluids/medicines injected[15].

Venous cannulation with PIVCs is associated with complications, which can be infectious, mechanical, or vascular. Potential infectious complications include bacterial/fungal, local or life-threatening bloodstream infections. Bloodstream infections lead to extended hospitalisation, higher treatment costs and increased mortality[16,17]. Potential mechanical complications include occlusion, dislodgement, infiltration, and extravasation. Vascular complications include venous thrombotic occlusion and phlebitis. Mechanical and vascular complications lead to device failure and the need to replace the PIVC, which results in interrupted therapy, pain associated with device replacement, and further health care costs associated with additional resources and staff time[12].

The interactions believed to cause mechanical and vascular complications are multifaceted, and good flushing and/or patency practice could mitigate these. Commonly, a fibrin coating forms within the PIVC lumen and catheter tip within 24 hours of placement. Fibrin can form the basis for thrombus development, which in turn can occlude the PIVC lumen and even the vessel[18]. Similarly, inappropriate concentrations of injected/infused solutions or incompatible mixtures can cause fluids or medications to precipitate within the catheter lumen and may obstruct the catheter[19]. Blood sampling through the PIVC or transfusion of blood products may further coat the internal lumen, encouraging clot formation.

Strategies to maintain PIVC patency include continuous infusion or intermittent flushing with saline solution[20-22]. The results of research comparing continuous infusion versus intermittent flushes to maintain PIVC patency remain inconclusive, with studies yielding conflicting results as well as having methodological issues related to design, sample size, and outcome indicators[23,24]. One non-randomised study suggested pre-filled flush syringes can reduce bloodstream infections, over manually filled syringes[25]. Additionally, a small paediatric trial (n = 400), which demonstrated daily flushing was as effective as twice-daily flushing with prefilled flushes used in both groups, reported very low PIVC failure rates (13%) across the entire cohort[26]. These failure rates were in contrast to the failure rates (45%) in a pilot trial of flushing regimens we led and in other PIVC research[1-3]. This discrepancy could be attributed to the use of prefilled flush syringes as standard across study groups. Ou pilot factorial randomised trial compared the effectiveness of different flushing frequencies (more vs less) and volumes (high vs low) to prevent PIVC to prevent PIVC failure[1]. The primary outcome of PIVC failure was comparable across groups; however, the final regression analysis found the rate of episodes of access (combined flushes and medication injections HR 1.25) significantly associated with PIVC failure (in addition to site choice and gender). These results suggested that it may not be the flush per se, but rather excessive injection pressures (shear force) possible with manual flushes that damage the vessel intima, by direct pressure and/or by haemodilution activating the endothelium[19].

The goal of good patency practice (flushing or infusion) should be to maintain flow similar to the vein flow rate and profile. Current policy is inconsistent and evidence for frequency of flushing, flush volumes, flush pressure and use of pulsatile techniques is either lacking or poorly translated into practice. Indeed flushing practice itself is poorly documented and quantified. The purpose of this study was to conduct a detailed observational study of nurse medication and intravenous (IV) administration/care practice in the clinical area.

METHOD

Design

This was a single-centre, prospective observational study of IV medication and flush administration on surgical and medical wards of a tertiary metropolitan hospital. Hospital and Health Service District as well as University ethics committee approval was obtained (HREC/15/QRBW/488 and GU Ref 2015/788).

Study aims

The aim of the study was to describe and quantify nursing modes, methods and duration related to IV medication and flush administration in the clinical setting and compare to current recommended flushing and patency practice.

Sample and setting

Potential participants included registered nurses from surgical and medical wards in a large metropolitan hospital. Information sessions were conducted at handover and potential participants were provided written information and gave verbal consent. Consenting nurses were observed over two-hour periods from a range of shifts, while administering IV medications or flushes.

Data collection and outcome variables

Research nurses (ReNs) were employed to observe and collect data. These ReNs were experienced registered nurses with advanced knowledge of IV insertion and maintenance. They shadowed consenting participants and collected data using an electronic-based tool focusing on three key phases of IV medication/flush administration — preparation, administration, and documentation. The data collection tool was piloted and subjected to face validity testing prior to use in the main study. The original data collection tool had to be amended and reformatted to capture the different methods of delivery observed in the pilot phase. As well as timing of each phase, ReNs noted adherence/deviation from principles of aseptic non-touch technique (ANTT), equipment used, use/no use of saline flush, medication type, time and mode of push. PIVC characteristics and condition (state of dressing, patency of catheter) were assessed by the attending nurse prior to medication and/or flush delivery. Ward and patient demographics were collected by ReNs to summarise staffing and patient population to assist with interpretation and generalisability of results.

Analysis

Data were entered into an electronic case report form using REDCap (Research Electronic Data Capture)[27] then exported to PASW (SPSS Inc Chicago). Descriptive statistics were used to summarise data, counts with percentages, and mean with standard deviation. These were then compared to the IV maintenance policy of the institution, which is based on the Infusion Nurses' Society (INS) guidelines[15,28].

Ethical considerations

There were no foreseeable risks through the conduct of, or participation in, this study. There was no new practice being tested nor was any aspect of practice/treatmen manipulated or withheld. Patients were not the subject of this observational study and no identifying patient data was collected. Patients were given an information sheet outlining the study objectives and process for their information. All staff involved in the study were given verbal and written information about the study. Staff were asked for their verbal consent to be observed for the duration of each data collection period as per the approved protocol. Participation was voluntary and staff could withdraw from the study without penalty. Confidentiality and anonymity of results was assured. No individual was under investigation. Only aggregate results are published.

Quality assurance

It had been planned that if the observer determined a possible significant deviation from the medication order (wrong patient, medication, dose, route or time) or policy (lack of adherence to all steps), they would discreetly ask the nurse to clarify the order or practice and be given the opportunity to circumvent the error, with further clarification from the supervising nurse. These incidences were planned to be recorded as potential medication errors. However, no significant potential medication breaches were observed. Deviations from recommended hand hygiene and or ANTT measures were picked up and corrected at the time.

RESULTS

Eighty-two nurses were observed yielding 82 sets of observations on the same number of patients. Most observations were for PIVCs (n = 77; 93%), with the remainder on peripherally inserted central catheters (PICCs). The majority of nurse participants (n = 67; 82%) were new graduates or had accrued up to 5 years' experience. The overwhelming majority of participants were registered nurses with a very small minority of clinical nurses.

Method of administration

All IVs were in situ for a reason, i.e., antibiotic administration or fluid replacement. The method of medication and/or flush administration was distributed as follows: IV bolus (n = 28; 34%); IV medication in a bag (n = 36; 44%); and IV burette (n = 18; 22%) (see Table 1).

Table 1: Method of administration

Method of administration	Variable	n (%)
IV bolus (n = 28)		
IV bolus location	Extension	17 (61)
	Y-line	5 (18)
	Needleless connector	6 (21)
Medication type	Antibiotic	13 (46)
	Flush only	3 (11)
	Other	12 (43)
Pre-drug administration flush	Yes	24 (86)
	No	2 (7)
	Missing data	2 (7)
Pulsatile flush	Yes	5 (18)
	No	22 (79)
	Missing data	1 (4)
Post-drug administration flush	Yes	24 (86)
	No	2 (7)
	Missing data	2 (7)
IV bag (n = 36)		
How the administration set was attached	Y-site	4 (11)
	3-way tap	20 (56)
	Extension tubing	4 (11)
	Direct to device	8 (22)
Medication type	Antibiotic	29 (80)
	Narcotic	1 (4)
	Heparin	3 (8)
	Other	3 (8)
Volume of dilution	100 mL	21 (58)
	250 mL	10 (29)
	500 mL	2 (7)
	50 mL	3 (8)
Pre-drug administration flush	Yes	0 (0%)
	No	36 (100%)
Post-drug administration flush	Yes	0 (0%)
	No	36 (100%)
IV burette (n = 18)		
Flush burette connector	Yes	12 (67)
	No	6 (33)
Medication type	Antibiotic	18 (100)
Pre-drug administration flush	Yes	0 (0%)
	No	18 (100%)
Post-drug administration flush	Yes	5 (28)
	No	13 (72)
Fluid/medication delivery		*Mean (SD)*
Rate of infusion (mL/hr)		107 (±81)
Volume to be infused (mL)		130 (±41)

Of the 28 bolus administrations, the majority were for medication administration (n = 25/28; 89%) and delivered via an extension line (n = 17/28; 61%). Pre and post medication administration flushes were delivered in all cases, with pulsatile delivery used in a minority of occasions (n = 5/28; 18%). Of the 36 IV bag administrations, the majority were delivered via a 3-way tap in 100 mL bags (n = 21/28; 58%). Pre and/or post flushes were not observed for any administration in this group. Of the administrations delivered using an IV burette the average volume was 130 mL (± 55 mL), for delivery of antibiotics. The burette connector was flushed pre administration on 12 (67%) occasions and post administration on 5 (28%) occasions. Overall, most flushes (when given) used 10 mL syringes with 0.9% sodium chloride (91%).

ANTT and infection control

Infection control practice and adherence to ANTT principles were observed in the preparation phrase and throughout each mode of administration (see Tables 2 and 3). Nearly one third of nurses were not fully compliant with either hand hygiene or principles of ANTT in the preparation phase. A quarter of nurses experienced interruptions (n = 23; 26%). Half of the nurses (n = 45; 54%) were not fully compliant with hand hygiene post preparation. Needleless decontamination was conducted in 99% of cases, with median scrubbing times ranging from 3.00–4.50 seconds (Q1 2.00, Q3 6.00) and median drying times 3.00–4.00 seconds (Q1 1.75, Q3 8.00) depending on method of administration.

Table 2: Medication and flush preparation

Preparation (n = 82)	Compliance	n (%)
Hand hygiene	Yes	56 (68)
(Pre-preparation)	No	26 (32)
ANTT principles	Yes	55 (67)
(throughout procedure)	No	27 (33)
Hand hygiene	Yes	38 (46)
(Post-preparation)	No	44 (54)
Interruptions	Yes	21 (26)
(during procedure)	No	61 (74)

Table 3: Infection control

Needleless connector management		Result
IV bolus (n = 28)		
Decontamination solution 70% IPA *N (%)*		
	Yes	28 (100)
Scrub time (secs) *Median (Q1, Q3)*		4.5 (2.25, 6.00)
Drying time (secs) *Median* (Q1, Q3)		4.00 (2.00, 8.00)
IV Bag administration (n = 36)		
Decontamination Solution *N (%)*		
	Yes	27 (75)
	N/A	9 (25)
Scrub time (secs) *Median* (Q1, Q3)		3.00 (2.00, 5.00)
Drying time (secs) *Median* (Q1, Q3)		3.00 (2.00, 5.00)
IV Burette (n = 18)		
Decontamination solution 70% IPA *N (%)*		
	Yes	17 (94)
	No	1 (6)
Scrub time (secs) *Median* (Q1, Q3)		3.00 (2.00, 5.00)
Drying time (secs) *Median* (Q1, Q3)		3.00 (1.75, 5.00)

IPA = Isopropyl alcohol; Q1 = 1st quartile; Q3 = 3rd quartile

DISCUSSION

The aim of this study was to observe and describe the IV flush and medication administration practices of nurses on medical and surgical wards at a tertiary metropolitan hospital. Observations highlighted the variation and inconsistency in IV medication and flush administration. Flushing and medication administration practice was most consistent when delivered using bolus administration. However, medication and flush administration was highly varied when using 100 mL bags or burettes. The absence of pre or post medication administration flushing on occasion in this study has implications for vessel preservation and medication dosage. Not flushing the IV catheter pre medication administration means an infusion was commenced into a device and vein where patency was not confirmed, and therefore infusate may infiltrate into surrounding tissue. Post-study feedback revealed that although flushing was not observed, nurses anecdotally reported occasionally using a second 100 mL bag to flush the giving set. However, this was not observed or captured in this study. Not flushing the entire medication dose through the administration set means the patient will not have received the full medication dosage, which has implications for efficacy of patient treatment and length of stay.

Additionally, a residual amount of the medication dose/infusion will sit in the catheter and vein, potentially irritating the vessel and leading to phlebitis and device failure. Use of 100 mL bags also means repeatedly breaking the closed circuit delivery system and manipulation of the catheter, which may predispose the device to failure and/or infection. Although flushes were given on some occasions, pre and post burette delivery, these were delivered via the burette and not as a bolus delivery at the distal end of the line close to the cannula, negating the full patency assessment value of the flushing procedure.

The cost of using 100 mL bags and giving set is also a significant issue. This adds approximately an extra A$10.00–12.00 in consumables per episode (Queensland Health Standing Offer Arrangement). The local policy and generally accepted practice is that if a patient has two or more regular IV medications prescribed, an infusion is set up with a burette set to keep vein open (TKVO – approximately 10 mL/hr) in between medication doses[15,28]. This was only employed in one third of relevant cases in this study. Anecdotally, nurses report a reluctance to set up and maintain TKVO infusions either due to patient preference (for example, IV pole impairs/restricts mobility), and/or nursing preference (for example, patients with IV infusion in progress require nurse escort when transferred to radiology). So while the practice of TKVO is recommended in policy, it is not always accepted in the clinical setting. Furthermore, the merit of intermittent flushing even when an infusion is in progress appears not to be valued by nurses or policy makers, as it was not consistently performed pre- and/or post-medication administration and is not reinforced in the guidelines when an infusion is in progress. If the purpose of flushing is to promote and maintain patency of the IV catheter by preventing build-up of fibrin and precipitate and avoid mixing of incompatible fluids or medications, then it is imperative that the benefits of flushing with and without an infusion in progress are understood and operationalised. Preclinical studies have demonstrated the limitation of a continuous slow infusion in rinsing the PIVC of protein build up[29]. Furthermore, the act of flushing proximal to the catheter is an opportunity to assess the level of patency of the catheter and condition of the site; this opportunity is being missed in some cases.

No other studies have specifically observed or quantified flushing practice as we have done. However, a number of studies have observed IV medication administration in order to ascertain clinical factors and behaviour that contribute to IV medication errors. Disturbingly, a number of studies, including a systematic review, reported a probability of at least one error in 70% of administrations[30-32]. The more common reason for medication error was incorrect rate of delivery and issues with reconstitution[30,32]. The results from these studies suggest that poor adherence to IV flushing pre- and post-medication administration further contributes to an IV medication error through potential mixing of incompatible substances and failure to administer the full dose.

The build-up of precipitate in the IV catheter and vein can also lead to device failure through occlusion from clot formation or phlebitis. PIVC failure has been noted to be unacceptably high (averaging 40%) in a number of recent studies[1-3,33]. IV failure further compromises medication administration due to delayed delivery of treatment, as well as causing considerable patient discomfort and increased costs to the organisation. Australia uses approximately 20 million PIVCs annually for hospital patients, as derived from patient admission and IV use data (for example, in 2014–15 there were 10.2 million separations for Australian hospitals, and most patients require one or more PIVCs per admission[14])[34,35]. If 40% of these fail, at a replacement cost of $70 each, this costs over $550 million each year[12].

The issue of poor hand hygiene remains a problem across all aspects of healthcare and all disciplines and settings. The United States Centers for Disease Control and Prevention (CDC) report that, on average, healthcare providers clean their hands fewer than half the times they should[36]. However, figures from annual audits of 940 hospitals by Hand Hygiene Australia show a rise in the last five years in overall compliance with all steps by 16% (68% in 2011 to 84% in 2016)[37]. Figures from this study indicate only two-thirds of nurses follow all steps of hand hygiene. Health care-associated infection (HCAI) is a major problem for patient safety, and surveillance and prevention must be a first priority for settings and institutions committed to making health care safer[38]. Full compliance with hand hygiene and adherence to the steps and principles of ANTT are essential first line barriers to HCAI and must be promoted and facilitated by all health care providers. The State Health Authority (Queensland) has developed a Clean Hands Application that encourages regular audit and feedback to staff on their performance, as well providing a range of online, hard copy, and visual resources to promote good hand washing practice. A recent integrated review of evidence-based practices to increase hand hygiene has shown that a range of local and institution-wide programs are required to raise awareness of the issue and change practice. These programs should be multi-modal, engaging the user in a variety of ways, including audit and feedback, and considering alteration in facility design if necessary (for example, sink placement, alcohol-based hand rub dispensers[39]).

Factors known to contribute to deviation from policy and guidelines in clinical practice include complexity of task, access to essential equipment, lack of specific knowledge and or skill set, and/or behaviour learnt in the workplace that become routine violations learnt workplace behaviours and culture[32,39,40]. Recommended strategies to promote adherence to recommended practice include: supply of pre-prepared products (for example, medication, flushes) to reduce risk of error in reconstitution and contamination; pragmatic ward and workplace design (for example, location of sinks and preparation areas); and improving clinician awareness and knowledge through education, supervision, and feedback from practice audits. While prevention of catheter-related bloodstream infection (CR-BSI) has a high profile in research and practice, clinicians receive very little feedback on outcomes of IV devices (insertion and maintenance), particularly PIVCs. The limited studies in this area are likely to have contributed to its low profile as an important patient quality and safety issue.

There are some limitations with this study related to the observational design, setting, and sample size. We used an undisguised observational technique, and nurses were aware that our study was investigating flushing and medication administration practice. It is possible that nurses changed their behaviours when observed. The outcomes of this possible bias would be an underestimation of the 'true' error and procedural failure rates. However, the duration of the study and varied data collection reduces the likelihood of sustained behaviour change by nurses on busy hospital wards. Also, our study was conducted on a small group of Australian nurses and thus may not be generalisable to countries with different nursing practices.

CONCLUSION

Most PIVCs are in place for a reason, such as antibiotic administration, and therefore maintaining their function is paramount. There were mixed forms of medication delivery (predominantly use of single bags), which have implications for IV flushing practice and healthcare costs. Flushing practice was most consistent when using bolus delivery of medication. Nursing staff and policy makers are not aware of the need for flushing the line proximal to the cannula when infusions are in progress. Implementation studies and practice guidelines need to reiterate the need for flushing regardless of the mode of medication delivery to allow for adequate assessment of PIVC and vessel patency, as well prevent/reduce mixing of incompatible substances. Use of intermittent small bags and repeated breaking of IV circuit needs to be discouraged, to reduce infection risk and healthcare costs. Adherence to hand hygiene and ANTT was also suboptimal. Hand hygiene and ANTT are essential first line barriers to the development of HCAIs. Deviations from the key steps can have devastating consequences for patients. The results from this study indicate it is an area that requires ongoing work to instil the long-term attitudinal and behavioural changes required for full compliance. Regular audit and feedback of clinical process and outcomes and monitoring of mode of delivery and requirement for IV devices at clinical handover is recommended to motivate staff to adhere to practice recommendations.

REFERENCES

1. Keogh S, Flynn J, Marsh N, Mihala G, Davies K & Rickard C. Varied flushing frequency and volume to prevent peripheral intravenous catheter failure: A pilot, factorial randomised controlled trial in adult medical-surgical hospital patients. Trials 2016; 17:348.
2. Marsh N, Webster J, Flynn J et al. Securement methods for peripheral venous catheters to prevent failure: a randomised controlled pilot trial. J Vasc Access May–Jun 2015; 16(3):237–244.
3. Rickard CM, Webster J, Wallis MC et al. Routine versus clinically indicated replacement of peripheral intravenous catheters: a randomised controlled equivalence trial. Lancet Sep 22 2012; 380(9847):1066–1074.
4. Bausone-Gazda D, Lefaiver CA & Walters SA. A randomized controlled trial to compare the complications of 2 peripheral intravenous catheter-stabilization systems. J Infus Nurs Nov–Dec 2010; 33(6):371–384.
5. Chico-Padron RM, Carrion-Garcia L, Delle-Vedove-Rosales L et al. Comparative safety and costs of transparent versus gauze wound dressings in intravenous catheterization. J Nurs Care Qual Oct–Dec 2011; 26(4):371–376.
6. Forni C, D'Alessandro F, Gambino O et al. [Effectiveness of the transparent sterile dressing vs standard to fix the peripheral venous catheter (PVC) on the incidence of phlebitis. A randomized controlled trial]. Assistenza Infermieristica e Ricerca: AIR Apr–Jun 2012; 31(2):63–69.
7. Fujita T & Namiki N. Replacement of peripheral intravenous catheters. J Clin Nurs Sep 2008; 17(18):2509–2510.
8. Nassaji-Zavareh M & Ghorbani R. Peripheral intravenous catheter-related phlebitis and related risk factors. Singapore Med J Aug 2007; 48(8):733–736.
9. Nishanth S, Sivaram G, Kalayarasan R, Kate V & Ananthakrishnan N. Does elective re-siting of intravenous cannulae decrease peripheral thrombophlebitis? A randomized controlled study. Natl Med J India Mar–Apr 2009; 22(2):60–62.
10. Helm RE, Klasusner JD, Klemperer JD, Flint LM & Hung E. Accepted but unacceptable: Peripheral IV catheter failure. J Infus Nurs 2015; 38(3):190–203.
11. Krist AH, Glenn BA, Glasgow RE et al. Designing a valid randomized pragmatic primary care implementation trial: the my own health report (MOHR) project. Implement Sci 2013; 8:73.
12. Tuffaha HW, Rickard CM, Webster J et al. Cost-effectiveness analysis of clinically indicated versus routine replacement of peripheral intravenous catheters. Appl Health Econ Health Policy Jan 10 2014; 12(1):51–58.
13. Keogh S, Flynn J, Marsh N, Higgins N, Davies K & Rickard C. Nursing and midwifery practice for maintenance of vascular access device patency: A cross-sectional survey. Int J Nurs Stud 2014; 52(11):1678–1685.
14. Alexandrou E. The One Million Global Catheters PIVC worldwide prevalence study. Br J Nurs Apr 24–May 7 2014; 23(8):S16–17.
15. Infusion Nurses Society. Infusion Nursing Standards of Practice. J Infus Nurs 2016; 39(1S).
16. Maki DG & Ringer M. Risk factors for infusion-related phlebitis with small peripheral venous catheters. A randomized controlled trial. Ann Intern Med May 15 1991; 114(10):845–854.
17. Malach T, Jerassy Z, Rudensky B et al. Prospective surveillance of phlebitis associated with peripheral intravenous catheters. Am J Infect Control Jun 2006; 34(5):308–312.
18. Baskin JL, Pui CH, Reiss U et al. Management of occlusion and thrombosis associated with long-term indwelling central venous catheters. Lancet Jul 11 2009; 374(9684):159–169.
19. Hadaway L. Technology of flushing vascular access devices. J Infus Nurs May–Jun 2006; 29(3):129–145.
20. Goode CJ, Titler M, Rakel B et al. A meta-analysis of effects of heparin flush and saline flush: quality and cost implications. Nurse Res Nov–Dec 1991; 40(6):324–330.
21. Peterson FY & Kirchhoff KT. Analysis of the research about heparinized versus nonheparinized intravascular lines. Heart Lung Nov 1991; 20(6):631–640.
22. Randolph AG, Cook DJ, Gonzales CA & Andrew M. Benefit of heparin in peripheral venous and arterial catheters: systematic review and meta-analysis of randomised controlled trials. Br Med J Mar 28 1998; 316(7136):969–975.
23. Fernandez RS, Griffiths RD & Murie P. Peripheral venous catheters: a review of current practices. J Infus Nurs Nov–Dec 2003; 26(6):388–392.
24. Flint A, McIntosh D & Davies MW. Continuous infusion versus intermittent flushing to prevent loss of function of peripheral intravenous catheters used for drug administration in newborn infants. Cochrane Database Syst Rev 2005; 4:CD004593.
25. Bertoglio S, Rezzo R, Merlo FD et al. Pre-filled normal saline syringes to reduce totally implantable venous access device-associated bloodstream infection: a single institution pilot study. J Hosp Infect Mar 13 2013; 84(1):85–88.
26. Schreiber S, Zanchi C, Ronfani L et al. Normal saline flushes performed once daily maintain peripheral intravenous catheter patency: a randomised controlled trial. Arch Dis Child Jan 14 2015; 100(7):700–703.

27. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N & Conde JG. Research electronic data capture (REDCap) — a metadata-driven methodology and workflow process for providing translational research informatics support. J Biomed Inform Apr 2009; 42(2):377–381.
28. Queensland Health. Insertion and management of central venous catheters guidelines. In: Centre for Healthcare Related Infection Sureveillance and Prevention (CHRISP), ed. Brisbane, Australia: Queensland Government; 2011.
29. Guiffant G, Durussel JJ, Merckx J, Flaud P, Vigier JP & Mousset P. Flushing of intravascular access devices (IVADs) — efficacy of pulsed and continuous infusions. J Vasc Access Jan–Mar 2012; 13(1):75–78.
30. Han PY, Coombes ID & Green B. Factors predictive of intravenous fluid administration errors in Australian surgical care wards. Quality and Safety in Health Care Jun 2005; 14(3):179–184.
31. McDowell SE, Mt-Isa S, Ashby D & Ferner RE. Where errors occur in the preparation and administration of intravenous medicines: a systematic review and Bayesian analysis. Quality and Safety in Health Care Aug 2010; 19(4):341–345.
32. Westbrook JI, Rob MI, Woods A & Parry D. Errors in the administration of intravenous medications in hospital and the role of correct procedures and nurse experience. BMJ Qual Saf Dec 2011; 20(12):1027–1034.
33. Wallis MC, McGrail M, Webster J et al. Risk factors for peripheral intravenous catheter failure: a multivariate analysis of data from a randomized controlled trial. Infect Control Hosp Epidemiol Jan 2014; 35(1):63–68.
34. AIHW. Australian Hospital Statistics. In: AIHW, ed. Canberra 2014–2015.
35. Autralian Institute of Health and Welfare. Australian hospital statistics 2012–2013. Canberra: AIHW; 2014.
36. Centers for Disease Control. Hand Hygeine in Health Care Settings. 2016; https://http://www.cdc.gov/handhygiene/.
37. Hand Hygeine Australia. National Audit Data. 2017; http://www.hha.org.au/LatestNationalData.aspx.
38. WHO. WHO Guidleines on Hand Hygeine in Health Care. First Glbal Patient Safety Challenge: Clean Care is Safer. 2009. http://apps.who.int/iris/bitstream/10665/44102/1/9789241597906_eng.pdf.
39. Neo JR, Sagha-Zadeh R, Vielemeyer O & Franklin E. Evidence-based practices to increase hand hygiene compliance in health care facilities: An integrated review. Am J Infect Control Jun 1 2016; 44(6):691–704.
40. Reason J. Human Error. Cambridge: Cambridge University Press; 1990.