Volume 1 Issue 2
NOVEMBER 2015
ISSN: 2204-9762

ORIGINAL ARTICLE

Randomised controlled trials in peripheral vascular access catheters: a scoping review

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INTRODUCTION

The majority of hospital patients require at least one peripheral vascular device for blood tests or for the delivery of intravenous fluids and medications during their hospital stay. These catheters include peripheral intravenous, midline, and arterial catheters. Despite the ubiquity of peripheral catheters in hospital care, the rate of complications and failure of these devices is reported to be as high as 34%[1-3] demonstrating the need for a much greater investment in research to reduce associated patient discomfort, delays in necessary medical treatments, and prolonged length of hospital stay. The Alliance for Vascular Access Teaching and Research (AVATAR) group, based at Griffith University in Brisbane, Australia, has a proven track record in conducting robust research into all facets of vascular access. With time and resource limitations a reality, the research agenda needs to incorporate targeted strategies so that studies can be conducted to best address patient needs and minimise duplication and costs.

Well-designed and executed randomised controlled trials (RCTs) provide reliable evidence with minimal bias compared to other study designs and are therefore considered the "gold standard" for evaluating the effectiveness of interventions[4]. Systematic reviews evaluate the combined results of RCTs, analyse for bias, and provide an even higher level of evidence. Clinical guideline developers and health care staff rely on quality RCTs and systematic reviews to guide decision-making in clinical practice, but the evidence in many areas is insufficient, with few RCTs, small sample sizes, poor reporting, and a lack of strong effect, meaning that findings cannot be generalised to a broader population[5].

A scoping study or review is an excellent methodology for mapping the extent, range, and nature of existing literature in a current topic area[6,7]. Less comprehensive and time-consuming than a systematic review, a scoping study is ideally suited to mapping the existing research in a given field and highlighting the gaps in evidence. A scoping study generally examines all literature published in a given field, regardless of study design[6], and in this review we sought to discover which topics in peripheral vascular devices have been well-researched, and to identify areas lacking in high-level evidence. Results from this review may provide unique insights that are useful for vascular access clinicians and researchers.

Aims of the scoping review

The review focused on answering the following research questions: What RCTs have been conducted with peripheral vascular devices in the past decade? What patient populations have been included? Which types of interventions have been studied? What are the outcome measures of these RCTs?

METHODS

Review framework

The scoping review was conducted along the following framework, outlined by Arksey and O'Malley[6] and modified by the Cochrane Public Health Group[7]: 1. Identify the research question; 2. Identify relevant studies; 3. Select studies for inclusion; 4. Sort, collate and analyse data; and 5. Summarise and report results. The investigators engaged in a reiterative consultation process of the scoping framework and inclusion/exclusion criteria to ensure consistency in decision making.

Identifying relevant studies

The search strategy was developed with the assistance of a university health sciences librarian. Inclusion and exclusion criteria were developed at the outset of the search. We included RCTs (including quasi-randomised trials) and systematic reviews published in English between 1 January 2005 and 30 June 2015 that focused on peripheral vascular devices, including peripheral intravenous catheters (PIVC), midline catheters (MC), and arterial catheters (AC). We included all participant ages and settings (inpatient and ambulatory). Systematic reviews were included in the search terms so we could examine the reference lists to identify potentially relevant RCTs. We excluded non-randomised controlled trials, secondary analysis of RCTs, and RCTs pertaining solely to central access catheters. Databases searched were Pubmed, Cochrane Central Register of Controlled Trials, and CINAHL. (See Appendix A for search terms.)

Study selection and data extraction

Titles and abstracts were initially screened for relevance. If the abstract was considered to meet the inclusion criteria, or if the reviewers were uncertain about inclusion, full text articles were then obtained and evaluated. Two reviewers read the full text of each article included in the final analysis.

Data sorting, collating and analysis

We used an Endnote library to sort the references into catheter type and then created a Microsoft Excel file to organise the data into the following headings: author(s); year of publication; study location; first author profession; study population (inpatient/ambulant neonates/paediatrics/adults, clinical specialities); sample size; intervention and comparator; outcome measures; and grant funding. Two researchers (MT and GRB) independently reviewed each article for themes and met on several occasions to discuss the findings and achieve consensus. Unlike a systematic review, a scoping study does not seek to assess the quality of evidence[6]. While other researchers have argued that a quality analysis is an important component of a scoping study[8], we did not analyse the quality of the evidence because the purpose of this review was to create a snapshot of the RCTs already conducted with peripheral vascular catheters and to point the way forward for further research. Authors were not contacted for further information.

Summarising and reporting results

After the data was organised into themes, we produced some preliminary tables. This enabled us to identify areas that had been the focus of RCTs and areas where the evidence was lacking.

RESULTS

Database searching identified 2528 studies and reference list searching identified a further 27 studies. (See Figure 1 for the flow chart of articles screened for inclusion in the scoping review.) After duplicates were removed, we screened the remaining abstracts for the inclusion and exclusion criteria. We reviewed the full text of 281 articles, of which 128 RCTs (94 PIVC, 2 MC, 32 AC) met the criteria and were included in the final review.

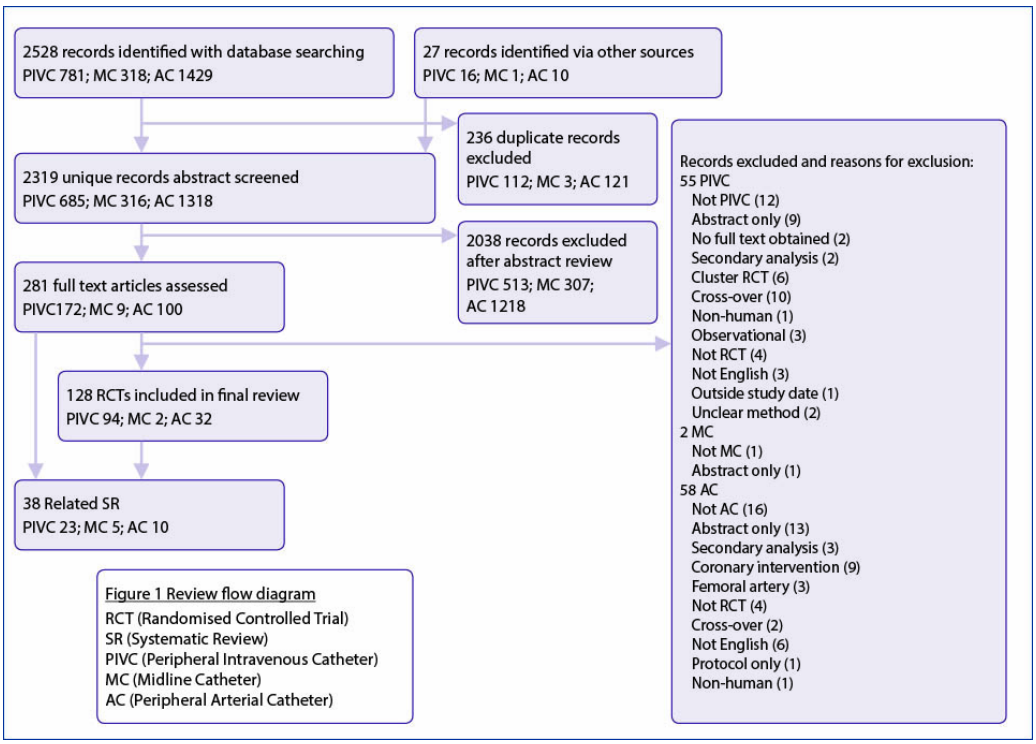

Figure 1. Flow chart of articles screened for inclusion in the scoping review

Peripheral vascular catheter RCTs were most commonly conducted in adults (75.2%) and inpatient settings (84%) (see Table 1) Countries conducting the most RCTs included the USA (44 trials), Australia (15 trials), Turkey (10 trials), Spain (8 trials), France (6 trials) and Japan (6 trials); these comprised 69.5% of the RCTs (see Figure 2). Nine multi-centre RCTs were identified (7 PIVC, 2 AC), with the remainder of studies being conducted in a single site. Six stated pilot RCTs were identified (3 PIVC, 3 AC). Although the majority of studies focused on a single catheter type (86 PIVC, 1 MC, 29 AC), a handful included more than one catheter type in the research protocol, so these were only included if results were presented separately for each catheter type.

Table 1. Population and setting in included RCTs

	PIVC n (%)	MC n (%)	AC n (%)	*Total* n (%)
Population (number of participants)				
Adult	13,323 (70%)	270 (100%)	6,613 (87.6 %)	20,206 (75.2%)
Paediatrics and neonates	5,731 (30%)	0 (0%)	944 (12.4 %)	6,675 (24.8%)
Total	19,054 (100%)	270 (100%)	7,557 (100%)	26,881 (100%)
Setting (number of studies)				
Inpatient	79 (84%)	2 (100%)	32 (100%)	113 (88.3%)
Outpatient	12 (13%)	0	0	12 (9.1%)
Both	2 (2%)	0	0	2 (1.6 %)
Not stated	1 (1%)	0	0	1 (1%)
Total	94 (100%)	2 (100%)	32 (100%)	128 (100%)
Clinical setting (number of studies)				
Adult ICU/CCU	4 (4.3%)	0	14 (43.8%)	18 (14.1%)
PICU	1 (1.1%)	0	2 (6.2%)	3 (2.3%)
NICU	6 (6.4%)	0	1 (3.1%)	7 (5.5%)
OT	6 (6.4%)	0	14 (43.8%)	20 (15.6%)
ED	27 (28.7%)	0	0	27 (21.1%)
Medical/Surgical	37 (39.4%)	2 (100%)	0	39 (30.5%)
Haematology/Oncology	2 (2.1%)	0	0	2 (1.6%)
Other/not stated	11 (11.6%)	0	1 (3.1%)	12 (9.3%)
Total (%)	94 (100%)	2 (100%)	32 (100%)	128 (100%)

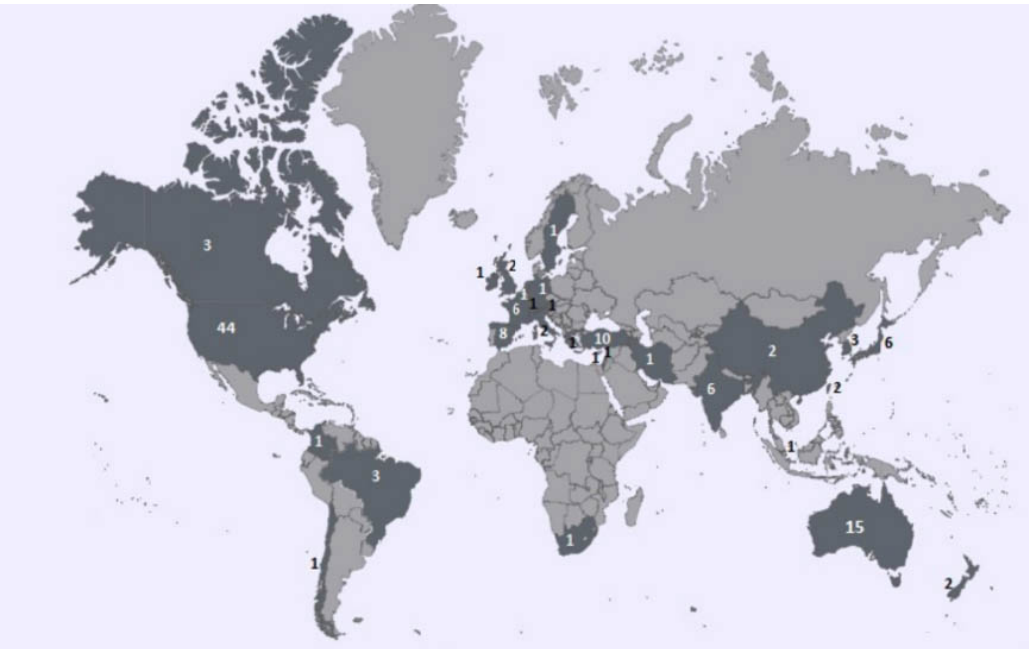

Figure 2. Number of published RCTs per country (January 2005 – June 2015)
Templates from http://www.amcharts.com/

The characteristics of the included RCTs, including catheter type, study topic, and clinical specialty, are presented in Table 2 Predominant topics studied in 94 PIVC RCTs included technology-guided catheter insertion (n=21, 22.3%) and analgesia pre-insertion (n=30, 32%), followed by add-on devices including needleless connectors and reflux valves (n=12, 12.8%), flushing solutions (n=8 8.5%), catheter indwell time (n=7, 7.4%), and dressings and securement methods (n=5, 5.3%). Predominant study topics in 32 AC RCTs included cannulation strategies (n=13, 40.1%) and flush solutions (n=7, 21.8%), followed by blood conservation (n=4, 12.5%) and dressings (n=4, 12.5%). The 2 RCTs in MCs respectively studied needleless connectors and anti-thrombolytic medications added to parenteral nutrition.

Table 2. Characteristics of the included RCTs

Catheter type and RCT topics	Number of studies by clinical area								
	Adult ICU/ CCU	PICU	NICU	OT	ED	Med/Surg	Haem Oncol	Other/ not stated	*Total (%)*
PIVC (n=94)									n=94 (%)
Blood collection methods					2[56,57]				2 (2.1%)
Cannulation: analgesia pre-insertion			1[58]	3[59-61]	14[62-75]	8[61,76-82]		4[83-86]	30 (32%)
Cannulation: education intervention						2[18,19]			2 (2.1%)
Cannulation: other technique							1[11]		1 (1.1%)
Cannulation: skin prep pre-insertion				1[87]		1[24]			2 (2.1%)
Cannulation: technology-guided	1[88]	1[89]		1[90]	8[91-98]	7[99-105]		3[106-108]	21 (22.3%)
Dressing/stabilising device/splint	1[37]		1[42]		1[38]	2[39,41]			5 (5.3%)
Flush/lock solutions			2[109,110]			6[111-116]			8 (8.5%)
Indwell time/line and device replacement						6[2,25,26,28,29,117]		1[27]	7 (7.4%)
Needleless connectors, reflux valves, add-on devices and different size of cannulae	1[118]			1[9]	2[119,120]	4[121-124]	1[10]	3[125-127]	12 (12.8%)
PIVC vs PICC			2[128,129]			1[130]			3 (3.2%)
Phlebitis prevention	1[131]								1 (1.1%)
MC (n=2)									n=2 (%)
Valve connectors						1[36]			1 (50%)
Flush/lock solutions						1[132]			1 (50%)
AC (n=32)									n=32 (%)
Blood conservation methods	3[31,133,134]	1[35]							4 (12.5%)
Blood glucose monitoring	1[135]								1 (3.1%)
Cannulation: analgesia pre-insertion				1[12]					1 (3.1%)
Cannulation: different gauges				2[136,137]					2 (6.3%)
Cannulation: other technique				6[138-143]					6 (18.8%)
Cannulation: technology-guided				4[144-147]				1[148]	5 (15.6%)
Dressings	4[1,32,33,149]								4 (12.5%)
Flush solutions	4[150-153]	1[154]	1[155]	1[156]					7 (21.8%)
Needleless connectors	2[30,157]								2 (6.3%)

RCT (randomised controlled trial), PIVC (peripheral intravenous catheter), MC (midline catheter), AC (peripheral arterial catheter), PICC (peripherally inserted central catheter), ICU (intensive care unit), PICU (paediatric intensive care unit), NICU (neonatal intensive care unit) OT (operating theatre), ED (emergency department), Med/Surg (medical and/or surgical wards), Haem/Oncol (haematology and/o oncology wards).

The reported outcome measures were sorted into broad categories (see Table 3): 1. Patient outcomes (pain, anxiety, satisfaction, length of hospital stay, survival/death); 2. Catheter insertion outcomes (cannulation success rate, time to catheterisation, number of attempts ease of cannulation, insertion difficulties); 3. Catheter complications (unplanned removal, dislodgement, extravasation, infiltration obstruction, rupture, skin reactions, thrombosis); 4. Other catheter outcomes (catheter dynamics and flow rate, dwell time, patency venous reflux); 5. Infective outcomes (CRBSI, colonisation, local infection, phlebitis, thrombophlebitis); 6. Blood sampling (blood loss haemolysis of samples, sampling techniques); 7. Flushing and lock solution (heparin, manual flushing); and 8. Health services outcomes (cost-effectiveness). We also located a range of systematic reviews and one meta-analysis examining RCTs in peripheral catheter and these are displayed in Table 4.

*Table 3. Outcome measures studied per catheter type**

Outcome measures	Number of RCTs per catheter type		
	PIVC	MC	AC
Patient outcomes			
Pain during insertion	32[58-62,64-83,85,86,91,93,106,119,158]		1[12]
Anxiety during insertion	2[11,84]		
Patient comfort/satisfaction during insertion	5[11,94,98,123,130]		
Patient/staff satisfaction			1[1]
Length of hospital stay	1[128]		
Survival rate or death	3[2,112,129]		
Catheter insertion outcomes			
Blood leakage during insertion	2[120,125]		
Cannulation success (first or second attempt)	17[18,19,63,82,89,90,95,97,99,100,102,103,105,107,108,120,123]		6[138,140-143,147]
Ease of cannulation	4[103,107,120,126]		
Number of catheters used to achieve insertion			1[144]
Need for further assistance during insertion			1[144]
Number of insertion attempts	19[11,80,88,89,91,93-96,98,100-102,104,106,107,123,128,129]		7[136,138,141,144-146,148]
Number of needle redirections	1[96]		
Time taken for successful insertion	18[11,82,88-91,93-96,98,100-102,104,106,107,137]		9[136,138,141-146,148]
Insertion failure	1[91]		
Catheter complications			
Pain/discomfort	7[37-39,112,115,123,127]		1[149]
Unplanned removal	8[26,29,37-39,41,123,124]		2[1,149]
Extravasation/leakage	10[37-39,42,112,115,123,124,127,129]		
Obstruction/occlusion	11[26,27,39,41,42,110,112,113,118,123,124]	2[36,132]	4[1,140,149,156]
Vessel-related	3[112,115,124]		7[136,139,140,145,148,154,156]
Not specified	2[24,107]		
Infiltration	7[26,28,38,41,116,118,123]		
Reduction in adverse events	1[121]		
Skin reaction			1[32]
Thrombosis	1[130]	1[132]	1[139,148]
Other catheter outcomes			
Catheter dynamics (vessel diameter and/or blood flow rate)	1[121]		1[105]
Dwell-time	7[2,110,112,113,116,122,123]	1[132]	4[1,136,150,154]
Functionality and patency	4[109,111,114,115]		5[136,151,153,155,156]
Venous reflux	1[10]		
Infective outcomes			
Catheter-related bloodstream infection	5[2,26,39,128,129]	1[36]	5[30,32,33,135,149]
Colonisation/contamination	4[2,9,23,122]		6[31-35,135]
Local infection	2[2,130]		3[1,149,156]
Phlebitis/local inflammation	18[2,26-28,37-39,41,42,110,113,116-118,122,123,128,131]		1[1]
Thrombophlebitis	2[25,113]		
Blood sampling			
Blood loss and haemoglobin level			2[133,134]
Blood transfusion required			1[134]
Coagulation testing			2[150,152]
Haemolysis of blood sample	2[56,57]		
Arterial blood gas sampling			1[136]
Flushing and lock solutions			
Heparin consumption			2[136,154]
Number of manual flushes			1[136]
Health service outcomes			
Cost-effectiveness	5[2,37,121,122,130]		1[1]

**Most RCTs included more than one outcome measure. RCT (randomised controlled trial), PIVC (peripheral intravenous catheter), MC (midline catheter), AC (peripheral arterial catheter)*

Table 4. Systematic review topic per catheter type

Topic of systematic review	PIVC	MC	AC
Patient outcomes			
Psychological interventions for pain and distress in paediatrics	1[159]		
Catheter insertion			
Ultrasound-guided cannulation	3[13-15]		1[160]
Catheter complications			
Frequency of PIVC replacement	3[161-163]		
Frequency of administration set replacement	2[164,165]	2[164,165]	2[165,166]
Dressing and securement devices	1[167]		
In-line filters	2[50,168]		
Other catheter outcomes			
Needleless closed catheter systems	1[51]	1[51]	
Long versus short PIVCs for delivering antibiotics in cystic fibrosis	1[169]		
Percutaneously inserted central catheters vs PIVCs for delivery of parenteral nutrition in neonates	1[170]		
Infective outcomes			
Chlorhexidine-impregnated dressings			1[40*]
CRBSI	2[171,172]	1[171]	3[55,171,173]
Phlebitis assessment scales	1[52]		
Aloe vera for phlebitis	1[174]		
Non-pharmacological interventions for preventing CRBSI	1[49]		
Educational interventions for preventing CRBSI	1[175]	1[175]	1[175]
Site of insertion and infection in burns patients			1[176]
Flushing and lock solutions			
Continuous vs intermittent flushing in infants	1[47]		
Low-dose heparin for PIVC patency in children	1[177]		
Heparin versus saline for AC patency			1[178]

**Meta-analysis*
CRBSI Catheter-related bloodstream infection

In the 128 RCTs reviewed, the primary author was a medical doctor in 73 (57.0%) studies and a nurse in 37 (28.9%) studies. Other first author professions included other professor/researcher (4, 3.1%), dentist (2, 1.6%), pharmacist (2, 1.6%), other (2, 1.6%), or not stated (8, 6.2%). Grant funding for studies was reported for 73 (57.0%) studies, and sources included a mixture of commercial (20, 15.6%), non-commercial (50, 39.1 %), and a combination of the two (3, 2.3 %).

DISCUSSION

This scoping review has revealed gaps in recent research relating to peripheral vascular devices. Firstly, paediatrics and neonates are still understudied across all peripheral catheter types, with much of the evidence being extrapolated from adult studies, and therefore likely not to be relevant for this population. However, although the absolute number of paediatric studies was small, sample sizes were not; paediatric patients comprised 24.8% of all study participants. Secondly, the majority (55%) of studies centred on cannulation (56 PIVC, 14 AC), with very little evidence available to guide maintenance care, such as catheter securement, dressing, and patency. Despite the importance of maintenance care in preventing catheter failure and infection, the only RCT examining catheter hub decontamination was conducted in the operating theatre[9], and no RCT examined flushing volume or frequency.

As expected, the highest proportion of PIVC RCTs was conducted in the emergency department (28.7%) or medical/surgical wards (39.4%). Studies of ACs mostly took place in the intensive care setting (43.8%) or operating theatre (43.8%). We found only two RCTs conducted in a haematology/oncology setting[10,11], which was particularly concerning as this patient cohort is likely to receive a high number of cannulations and experience venous depletion. We identified nine multi-centre RCTs, but the majority of studies were conducted in a single site, with small sample sizes, making the findings less amenable to generalisation. None of the identified pilo studies were followed up with larger definitive RCTs at the time of writing.

Recent evidence for peripheral catheter insertion has focused on pre-insertion analgesia and technology-guided insertion. Analgesia fo catheter insertion featured in 31 (24.2%) RCTs, primarily in PIVCs (n=30), but only one RCT studied this topic in ACs[12] and there were no relevant trials in MCs. Despite the prevalence of studies concerning pre-insertion analgesia, we did not find any systematic review of this topic. Technology-guided insertion featured in 26 (20.2%) of the 128 RCTs reviewed (21 PIVC, 5 AC). Three systematic reviews o ultrasound-guided cannulation of PIVCs have been published[13-15], but other insertion technology strategies, such as transmitted ligh devices, have yet to be comprehensively reviewed. Both the Centers for Disease Control and Prevention[16] and the Infusion Nurses Society[17] guidelines support ultrasound guidance for central catheter insertion, but neither has recommendations for the use o technology in peripheral device insertion.

We found no RCT that examined the impact of skilled inserters in the past 10 years. Two educational intervention RCTs targeted interns[18,19], but we found no RCTs of education programs for nurses. As nurses deliver the bulk of catheter care post-insertion, this is concerning and should be the focus for future research.

Strategies for the prevention of catheter-related bloodstream infection (CRBSI) historically have focused on central vascular access devices, but recent research has brought attention to the risk of infection with peripheral devices[20-22]. As the number of patients receiving peripheral catheters is much greater than central devices, it is surprising that we did not find more RCTs focusing on infection prevention. Skin preparation prior to cannulation is an understudied topic. Only two RCTs examined skin preparation solutions for PIVC insertion[23,24] and there were no studies on skin preparation before cannulation for ACs and MCs. A handful of RCTs examined post-cannulation preventative action for CRBSI in PIVCs, such as catheter hub disinfection stations in the operating theatre[9] and catheter replacemen policies[2,25-29]. The prevention of CRBSI or colonisation of ACs has been examined in recent RCTs conducted in adult ICUs[30-34], with only one study addressing the paediatric intensive care population[35]. Prevention of CRBSI related to needleless connectors was examined in one study in MCs[36].

In the adult population, two RCTs have examined the comparative effectiveness of PIVC dressing types[37] and securement[38], and two recent pilot RCTs in adults compared a range of dressings and securement methods in reducing catheter failure in PIVCs[39] and ACs[1], but no large multi-centre trials have been published. A meta-analysis in ACs concluded the benefits of chlorhexidine dressings in preventing catheter colonisation and CRBSI in high-risk adult and paediatric patients[40]. Dressing and securement studies are notably scarce in paediatrics. One RCT compared dressing types in this population[41], and one RCT found that limb immobilisation in neonates was ineffective in preventing PIVC failure[42]. As paediatric patients have different anatomy and may require different dressing techniques to secure the vascular device, studies in this area are needed and could add significant findings. We did not find any RCT that examined dressing and securement in MCs.

In this review of peripheral catheter RCTs, over two-thirds of research in this area was led by medical authors. This is perhaps not surprising because, firstly, medical staffs often have more access to paid research time and, secondly, the insertion of peripheral devices, particularly in patients with difficult vascular access, remains a medical responsibility in many hospitals. However, as nurses provide the bulk of catheter care post-insertion, and the catheter failure rate continues to be around 34%[1-3], we argue that it is essential to have more nurses undertake research in this area to determine why so many peripheral catheters fail, and test potential strategies for prevention in RCTs. For this to occur, nurses would need to be funded to incorporate research into their work, or health facilities would need to employ nurse researchers.

Sadly, only a small percentage of Australian National Health and Medical Research Funding is awarded to nursing studies. In the last five years, just 10 out of 2189 grants (0.35%) were awarded to applications coded under the nursing field of research[43]. This is disproportionately low, and disappointing to say the least. There are over 320,000 nurses working in Australia, and one per cent work in research roles[44]. Both nurses and the research system need to prioritise nurse-led research if it is to attract adequate funding to investigate and propose answers to clinical questions.

We used the Arksey and O'Malley framework for scoping studies to gain an understanding of the general landscape of recent RCTs in peripheral vascular catheters. This framework is well suited for this purpose. Some authors have criticised this methodology for not assessing the quality of evidence and determining the generalisability of evidence, but at this stage, there is no standardised method to assess the quality component of scoping reviews[45]. However, with respect to RCTs, this is the domain of a systematic review, and therefore analysis of bias of the included studies was beyond the scope of this review.

The designated time frame of the past decade is a potential limitation of the study, but the review sought to capture the current state of the evidence, rather than earlier and possibly outdated strategies for catheter insertion and care. For instance, technology-guided cannulation is a recent innovation and different kinds of catheters, dressings, securements and add-on devices are now in daily use. For practical reasons, research published in languages other than English was excluded because of the cost and time involved in translating material, and this may have screened out some relevant studies.

A major strength of this study is the limitation to RCTs and systematic reviews, as these provide the highest level of evidence to inform clinical practice[4]. Throughout the study, however, we anecdotally identified some poorly reported or conducted RCTs. Although RCTs are considered a "gold standard" of clinical evidence, if bias is evident or sample sizes are too small, the results may be inconsistent, lack strong effect, or fail to be generalisable to the specific clinical population[5]. Systematic reviews of various interventions for peripheral vascular devices repeatedly show that there is a need for more robust RCTs to be conducted in order to demonstrate powerful clinical effects[46-55].

CONCLUSION

This peripheral vascular catheter scoping review identified RCTs published in the past decade to enable clinicians and researchers to identify the gaps in evidence and prioritise areas needing further research. Although many RCTs examined catheter insertion strategies and analgesia methods, particularly for PIVCs, there were surprisingly few studies about the post-insertion care and maintenance of peripheral catheters, including dressings and securement, particularly in the paediatric population. More RCTs in this area are needed as well as studies on flushing practices and infection prevention strategies such as skin preparation and hub decontamination. As nurses provide the bulk of post-insertion catheter care, RCTs examining nursing education for catheter care are a priority. Evidence-based care will remain an elusive goal until the evidence base comprises quality RCTs to support daily clinical practice.

AUTHOR DISCLOSURES

Nil.

APPENDIX A: SEARCH TERMS

(((((((“arteries”[MeSH Terms] OR “arteries”[All Fields] OR “arterial”[All Fields]) AND (“catheters”[MeSH Terms] OR “catheters”[All Fields] OR “catheter”[All Fields])) OR (“vascular access devices”[MeSH Terms] OR (“vascular”[All Fields] AND “access”[All Fields] AND “devices”[All Fields]) OR “vascular access devices”[All Fields] OR (“arterial”[All Fields] AND “line”[All Fields]) OR “arterial line”[All Fields])) OR ((“arteries”[MeSH Terms] OR “arteries”[All Fields] OR “arterial”[All Fields]) AND (“equipment and supplies”[MeSH Terms] OR (“equipment”[All Fields] AND “supplies”[All Fields]) OR “equipment and supplies”[All Fields] OR “device”[All Fields]))) OR ((“haemodynamic”[All Fields] OR “hemodynamics”[MeSH Terms] OR “hemodynamics”[All Fields] OR “hemodynamic”[All Fields]) AND monitoring[All Fields])) AND (“blood vessels”[MeSH Terms] OR (“blood”[All Fields] AND “vessels”[All Fields]) OR “blood vessels”[All Fields] OR “vascular”[All Fields])) AND peripheral[All Fields]) AND (randomized controlled trial[pt] OR controlled clinical trial[pt] OR randomized[tiab] OR randomised[tiab] OR randomization[tiab] OR randomisation[tiab] OR “clinical trials as topic”[MeSH Terms:noexp] OR placebo[tiab] OR randomly[tiab] OR (“clinical trials as topic”[MeSH Terms] OR (“clinical”[All Fields] AND “trials”[All Fields] AND “topic”[All Fields]) OR “clinical trials as topic”[All Fields] OR “trial”[All Fields])) AND ((Randomized Controlled Trial[ptyp] OR systematic[sb]) AND (“2005/01/01”[PDAT] : “2015/06/30”[PDAT]) AND “humans”[MeSH Terms]) AND ((systematic[sb] OR Randomized Controlled Trial[ptyp]) AND “loattrfull text”[sb])

((midline[All Fields] OR (midline[All Fields] AND (“catheters”[MeSH Terms] OR “catheters”[All Fields] OR “catheter”[All Fields]))) AND ((Randomized Controlled Trial[ptyp] OR systematic[sb]) AND (“2005/01/01”[PDAT] : “2014/12/31”[PDAT]) AND “humans”[MeSH Terms]) AND (randomized controlled trial[pt] OR controlled clinical trial[pt] OR randomized[tiab] OR randomised[tiab] OR randomization[tiab] OR randomisation[tiab]) AND ((Randomized Controlled Trial[ptyp] OR systematic[sb]) AND “loattrfull text”[sb] AND (“2005/01/01”[PDAT] : “2015/06/30”[PDAT]) AND “humans”[MeSH Terms] AND English[lang])

(((((((peripheral[All Fields] AND intravenous[All Fields] AND (“catheters”[MeSH Terms] OR “catheters”[All Fields] OR “catheter”[All Fields])) OR (peripheral[All Fields] AND intravenous[All Fields] AND (“equipment and supplies”[MeSH Terms] OR (“equipment”[All Fields] AND “supplies”[All Fields]) OR “equipment and supplies”[All Fields] OR “device”[All Fields]))) OR PIV[All Fields]) OR (IV[All Fields] AND (“catheters”[MeSH Terms] OR “catheters”[All Fields] OR “catheter”[All Fields]))) OR PIV[All Fields]) OR IVC[All Fields]) OR IVD[All

Fields]) AND (randomized controlled trial[pt] OR controlled clinical trial[pt] OR randomized[tiab] OR randomised[tiab] OR randomization[tiab] OR randomisation[tiab] OR “clinical trials as topic”[MeSH Terms:noexp] OR placebo[tiab] OR randomly[tiab] OR (“clinical trials as topic”[MeSH Terms] OR (“clinical”[All Fields] AND “trials”[All Fields] AND “topic”[All Fields]) OR “clinical trials as topic”[All Fields] OR “trial”[All Fields])) AND ((Randomized Controlled Trial[ptyp] OR systematic[sb]) AND “loattrfull text”[sb] AND (“2005/01/01”[PDAT] : “2015/06/30”[PDAT]) AND “humans”[MeSH Terms] AND English[lang])

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