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Peripheral intravenous catheter infection and failure: A systematic review and meta-analysis

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ABSTRACT

Background: Peripheral intravenous catheters are the most frequently used invasive device in nursing practice, yet are commonly associated with complications. We performed a systematic review to determine the prevalence of peripheral intravenous catheter infection and all-cause failure.
Methods: The Cochrane Library, PubMed, CINAHL, and EMBASE were searched for observational studies and randomised controlled trials that reported peripheral intravenous catheter related infections or failure. The review was limited to English language and articles published from the year 2000. Pooled estimates were calculated with random-effects models. Meta-analysis of observation studies in epidemiology guidelines and the Cochrane process for randomised controlled trials were used to guide the review. Prospero registration number: CRD42022349956.
Findings: Our search retrieved 34,725 studies. Of these, 41 observational studies and 28 randomised controlled trials (478,586 peripheral intravenous catheters) met inclusion criteria. The pooled proportion of catheter-associated bloodstream infections was 0.028 % (95 % confidence interval (CI): 0.009–0.081; 38 studies), or 4.40 catheter-associated bloodstream infections per 100,000 catheter-days (20 studies, 95 % CI: 3.47–5.58). Local infection was reported in 0.150 % of peripheral intravenous catheters (95 % CI: 0.047–0.479, 30 studies) with an incidence rate of 65.1 per 100,000 catheter-days (16 studies; 95 % CI: 49.2–86.2). All cause peripheral intravenous catheter failure before treatment completion occurred in 36.4 % of catheters (95 % CI: 31.7–41.3, 53 studies) with an overall incidence rate of 4.42 per 100 catheter days (78,891 catheter days; 19 studies; 95 % CI: 4.27–4.57).
Interpretation: Peripheral intravenous catheter failure is a significant worldwide problem, affecting one in three catheters. Per peripheral intravenous catheter, infection occurrence was low, however, with over two billion catheters used globally each year, the absolute number of infections and associated burden remains high. Substantial and systemwide efforts are needed to address peripheral intravenous catheter infection and failure and the sequelae of treatment disruption, increased health costs and poor patient outcomes.

What is already known

- Peripheral intravenous catheters are the most common medical device placed in hospitals; however, they frequently fail requiring replacement.
- A 2006 systematic review reported a peripheral intravenous catheter-related bloodstream infection rate of 0.1 %, 0.5 per 1000 catheter days.
- No systematic review for local infections currently exists.

What this paper adds

- The peripheral intravenous catheter-related bloodstream infection rate was 0.044 per 1000 days, setting a new benchmark for healthcare facilities.

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- One third of peripheral intravenous catheters worldwide fail before the completion of treatment.
- Our results support the need for a system-wide, planned approach to improve the safety of these ubiquitous devices.

1. Introduction

Vascular access devices are essential to contemporary nursing, allowing the direct administration of supportive and interventional therapy into the bloodstream. Many different types of vascular access devices are in use, but the most common is the peripheral intravenous catheter (Tuffaha et al., 2018). Peripheral intravenous catheters are typically placed in superficial veins of the hand or forearm and are available in longer lengths to access deeper peripheral vessels. They are considered a quick, simple and cost-effective method to gain vascular access (Sabri et al., 2012) and up to 60 % of hospitalised patients receive at least one during their admission (Alexandrou et al., 2015).

Infections, in particular catheter-associated bloodstream infections, are the most serious complication associated with peripheral intravenous catheters (Moureau et al., 2019). The skin normally acts as a protective barrier against bacteria accessing the body but is breached when a catheter is inserted. Bacteria may enter the bloodstream via the external or internal surfaces of the catheter or may cause a local peripheral intravenous catheter related infection such as cellulitis or soft tissue infection (O'Grady et al., 2011). Consequently, catheter-associated bloodstream infections associated with peripheral intravenous catheters commonly consist of coagulase-negative *Staphylococcus* (common skin flora) bacteraemia and other organisms commonly found in hospital settings (e.g., *Staphylococcus aureus*) (Ruiz-Giardin et al., 2019). Microbial colonisation of a catheter can occur within 24 h of insertion and microbial biofilms can form within two to three days (Zhang et al., 2015). A scoping review including studies from 1966 to 2005 found that peripheral intravenous catheters have the lowest rate of catheter-associated bloodstream infections of all vascular access devices (0.1 % per peripheral intravenous catheter, 0.5 per 1000 catheter days) (Maki et al., 2006). Present-day peripheral intravenous catheter-associated bloodstream infection rates are less clearly defined (Mermel, 2017). However, the impact is clear. Catheter-associated bloodstream infections can increase healthcare costs by US$3000 to $56,000 per episode for treatment and prolong hospital admission on average 7 to 14 days (Dychter et al., 2012; Heng et al., 2020). Catheter-associated bloodstream infections also risk sepsis, multi-organ failure and mortality (Yan et al., 2021).

In addition to infection, a peripheral intravenous catheter can develop complications such as occlusion or phlebitis, leading to failure and premature catheter removal (Marsh et al., 2020). As well as having to treat the minor or serious complications associated with the sequalae of catheter failure (Helm et al., 2015), nursing workloads increase when catheters require replacement so patients can continue treatment. With over two billion peripheral intravenous catheters purchased each year (Rickard and Ray-Barruel, 2017) and catheter failure as high as 69 % in individual studies (Marsh et al., 2015a), catheter failure is a substantial adverse patient outcome and costly for healthcare facilities. Delays to time-sensitive treatments, such as chemotherapy or antibiotics, place patients at risk of preventable harm. Repeated peripheral intravenous catheter insertions can lead to venous access depletion (Hallam et al., 2016), increasing the possibility of a patient requiring a central venous access device, with a higher risk of significant complications and increased costs (Chopra et al., 2013; Marsh et al., 2021).

Whilst there are older reviews estimating peripheral intravenous catheter-associated infections, and individual studies reporting peripheral intravenous catheter failure, a reliable and contemporary estimation of the burden of these events has not been undertaken. The aim of this study was to determine the incidence of peripheral intravenous catheter infection and failure.

2. Methods

2.1. Search strategy and selection criteria

We followed the standard methods for conducting a systematic literature review and meta-analysis, and reported findings in accordance with the Cochrane process (Higgins et al., 2022), and MOOSE guidelines (Meta-analysis of observation studies in epidemiology) (Stroup et al., 2000).

We searched the Cochrane Library, PubMed, CINAHL, and EMBASE on the 26th of August 2022 to identify relevant cohort studies and randomised controlled trials that reported peripheral intravenous catheter failure or related infections (Supplementary Table 1). We also searched clinical trial registries (ClinicalTrials.gov, WHO International Clinical Trials Registry Platform, and EU Clinical Trials Registry) and manually reviewed the reference list of included studies to identify any additional studies. In consultation with a health librarian, a search strategy was developed that included appropriate medical subject heading terms such as: *Catheterization, Peripheral*; *Vascular Access Devices*; and *Infection*. We restricted the search to full-text published articles written in English. We pre-registered the study with the International Prospective Register of Systematic Reviews (crd.york.ac.uk/prospero/display_record.php?ID=CRD42022349956).

All cohort studies (prospective or retrospective) that investigated peripheral intravenous catheter failure and infection complications in adults requiring a peripheral intravenous catheter in a healthcare setting since the year 2000 were eligible. This timeframe was selected as it reflects the use of modern catheter polyurethane materials. Control groups from randomised controlled trials were similarly included as they represented usual practice (standard care) in the study setting. In addition, if the procedure in the intervention arm of any randomised controlled trials was consistent with international guideline recommendations (Loveday et al., 2014; Gorski et al., 2021) they were included. Case studies, non-peer reviewed publications, and qualitative research were excluded.

The outcomes of this review included: (1) peripheral intravenous catheter infection: a) catheter-associated bloodstream infections, the occurrence of bacteraemia in a patient with a peripheral intravenous catheter that was attributable to the device (O'Grady et al., 2011) and b) local infection, defined as evidence of infection at the insertion site; and (2) all-cause peripheral intravenous catheter failure defined as premature removal of the device before intended therapy was complete or replacement was otherwise indicated (excluding catheter-related infectious outcomes). Where available, we extracted the definition used to diagnose catheter-associated bloodstream infections and local infection from each study.

Review authors (NM, EL or GRB) independently assessed titles and abstracts for study inclusion. A fourth author's (AU) judgement was sought when differences of opinion were not resolved by unanimity or when review authors (NM, EL) were named on included studies. We also reviewed reference lists of retrieved studies to identify additional eligible reports. After screening, the full texts of eligible articles were retrieved.

2.2. Data extraction and quality assessment

Three review authors (NM, EL or CR) independently extracted data using a customised data extraction form. Any disagreement was resolved by a fourth author (AU) who also independently extracted data when NM, EL or CR was named on included studies. Where necessary, we attempted to contact study authors to collect missing data. Extracted data included: author name, year published, country, clinical setting, age, gender, study design, number of participants, exposure time, and incidence of outcomes.

Independently, three review authors (NM, EL, CR) assessed observational studies for quality and risk of bias using the following STROBE elements (The STrengthening the Reporting of OBservational studies

in Epidemiology statement: Guidelines for reporting observational studies): clear study objective; consistency and rigour of outcome measures; research methods; and completeness of outcome reporting (Vandenbroucke et al., 2014). Randomised controlled trials were assessed using the 'Risk of Bias' tool from the Cochrane Handbook of Systematic Reviews of Interventions (Higgins and Green, 2011).

2.3. Data analysis

Characteristics of the studies deemed eligible for data synthesis were presented using descriptive statistics. Proportions were presented as percentages, due to the relatively low proportion of events. Exact (Clopper–Pearson) confidence intervals were calculated for the individual studies. Proportions were pooled using one-stage, random intercept logistic regression models with the *metapreg* command in Stata (Rover and Friede, 2022). For meta-analysis of incidence rates, confidence intervals were calculated with Poisson regressions (Spittal et al., 2015).

A priori subgroup analyses included failures occurring in the emergency department vs other departments, study design (prospective vs retrospective), studies with ≥100 vs <100 participants, and study location (developed vs developing country) (United Nations, 2016). We assessed whether the proportion of failures varied by year with meta-regression and with a bubble plot of failure by year.

Heterogeneity was assessed using the I^2 (inconsistency index) adjusted for binomial-normal data (Zhou and Dendukuri, 2014), categorised as low (0–33 %), moderate (34–66 %), or high (64–100 %) (Stroup et al., 2000). Analysis was conducted using Stata 17 (Stata Corp, College Station, Texas, USA). For hypothesis testing, alpha was set at 0.05, two-tailed.

3. Results

The search generated 34,725 records. The Fig. 1 flowchart identifies the reasons for inclusion and exclusion, and is formatted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses checklist (Moher et al., 2009). After removing duplicates and screening titles and abstracts, 152 full-text articles were assessed for inclusion. Following full-text review, 83 articles were excluded as they either studied other vascular access devices (Thamby, 2007; Yilmaz et al., 2007; Renard et al., 2010), were audits (Brady et al., 2016; Powell et al., 2008; Chiu et al., 2015; Malach et al., 2006; do Rego Furtado, 2011), did not provide peripheral intravenous catheter incidence data (Jackson, 2012; Roszell and Jones, 2010; Karadeniz et al., 2003; Norton et al., 2013), had different outcome definitions (Aulagnier et al., 2014; Dunda et al., 2015; Groll et al., 2010; Coomarasamy et al., 2014; Kagel and Rayan, 2004; Oto et al., 2011; Prunet et al., 2008; Smith, 2006;

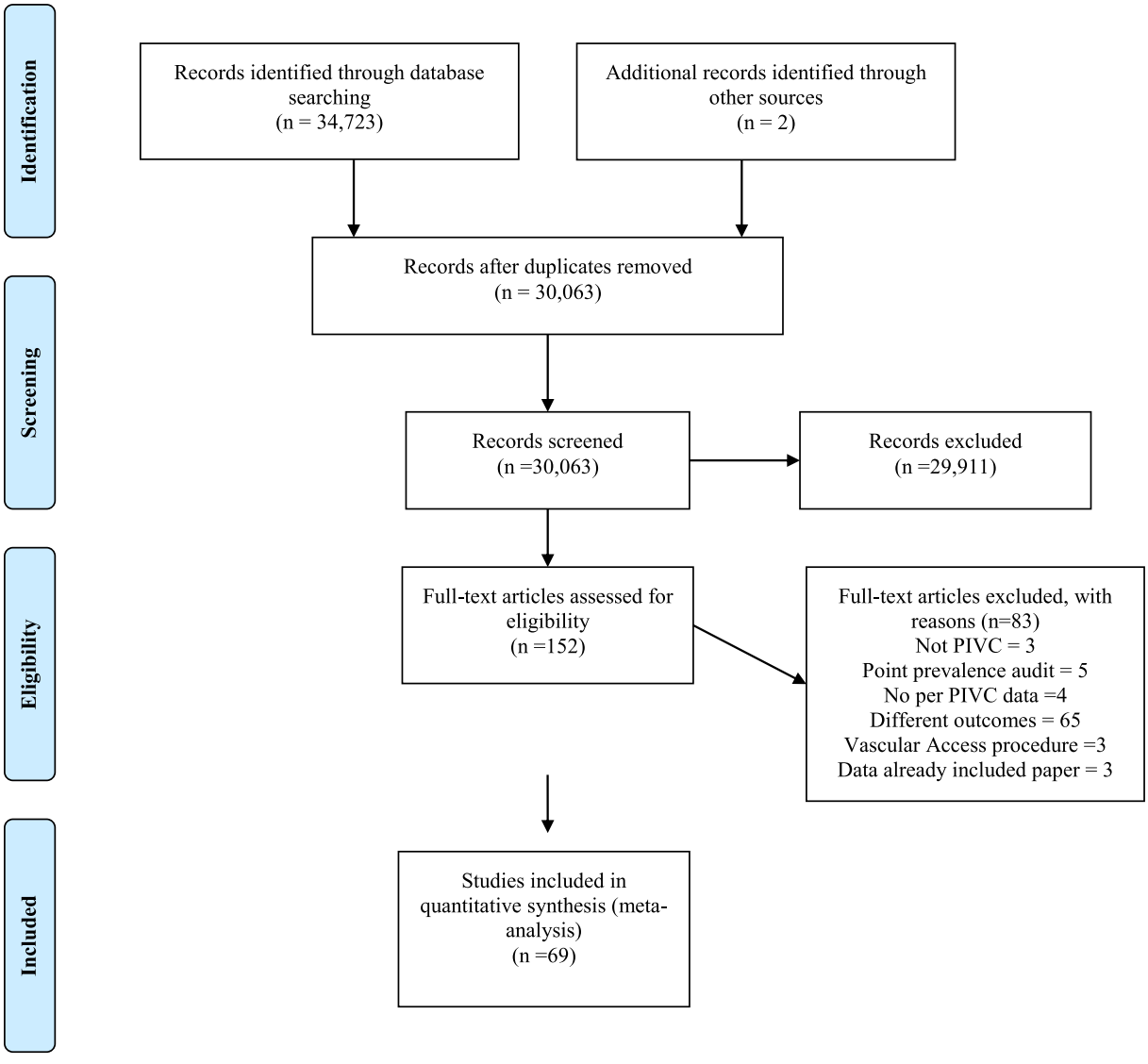

Fig. 1. PRISMA flow chart of study selection.

Table 1
Characteristics of the eligible studies

Author(s) (year)	Country	Study design (sample size)	Setting
Palefski and Stoddard (2001)	USA	Prospective (776)	Hospital wide; home infusion agency
Cornely et al. (2002)	Germany	Prospective (364)	Haematology; oncology; IDD
Creamer et al. (2002)	Ireland	Prospective (554)	MED; SURG
Royer (2003)	USA	Prospective (146)	MED; SURG
Taylor (2003)	Australia	Prospective (275)	MED; SURG
Vandenbos et al. (2003)	France	Prospective (390)	ED
Schears (2006)	USA	Prospective (15,004)	MED
Webster et al. (2007)	Australia	RCT (146)	MED; SURG
Dillon et al. (2008)	Ireland	Prospective (496)	MED; SURG
Fujita and Namiki (2008)	Japan	Prospective (368)	SURG
Periard et al. (2008)	Switzerland	RCT (29)	MED
Webster et al. (2008)	Australia	RCT (376)	MED; SURG
Lee et al. (2009)	Taiwan	Prospective (6538)	MED; SURG
Martínez et al. (2009)	Spain	RCT (332)	IDD
McNeill et al. (2009)	USA	Prospective (80)	MED; SURG; ED; radiology; ONC; renal therapy
Van Donk et al. (2009)	Australia	RCT (161)	Hospital in the home
Adhikari et al. (2010)	USA	Retrospective (764)	ED
Dargin et al. (2010)	USA	Prospective (75)	ED
Rickard et al. (2010)	Australia	RCT (323)	MED; SURG
Chico-Padrón et al. (2011)	Spain	RCT (29)	SURG; CCU
Elia et al. (2012)	Italy	RCT (50)	High dependency unit
Fakih et al. (2012)	USA	Prospective (4434)	MED; SURG
Fields et al. (2012)	USA	Retrospective (151)	ED
Mestre Roca et al. (2012)	Spain	Prospective (1201)	MED; SURG; ICU
Rickard et al. (2012)	Australia	RCT (3215)	MED; SURG
Salgueiro-Oliveira et al. (2012)	Portugal	Prospective (315)	MED
Mestre et al. (2013)	Spain	Prospective (2145)	Hospital wide
Abolfotouh et al. (2014)	Saudi Arabia	Prospective (842)	MED; SURG; IDD
González López et al. (2014)	Spain	RCT (599)	MED; SURG
Marsh et al. (2015a, 2015b)	Australia	RCT (21)	MED; SURG
Wang et al. (2015)	China	RCT (125)	Liver cirrhosis
Anderson (2016)	USA	Prospective (95)	MED; SURG; ICU; ED
Bugden et al. (2016)	Australia	RCT (190)	ED
Danski et al. (2016)	Brazil	RCT (79)	Clinical and surgical services
Enes et al. (2016)	Brazil	Prospective (122)	MED
Keogh et al. (2016)	Australia	RCT (160)	MED; SURG
Tan et al. (2016)	Singapore	RCT (307)	OB
Zhu et al. (2016)	China	Prospective (189)	ED
Miliani et al. (2017)	France	Prospective (815)	MED; SURG
Murayama et al. (2017)	Japan	Prospective (5316)	MED; SURG
Takahashi et al. (2017)	Japan	Prospective (200)	MED
Tan et al. (2017)	Singapore	Prospective (282)	MED; SURG
Xu et al. (2017a)	China	RCT (317)	Hepatobiliary surgical
Xu et al. (2017b)	China	RCT (645)	MED; SURG
Carr et al. (2018)	Australia	Prospective (391)	ED
Guihard et al. (2018)	Reunion (France)	Prospective (92)	ED
Marsh et al. (2018c)	Australia	Prospective (1578)	MED; SURG
Marsh et al. (2018a)	Australia	RCT (150)	MED; SURG
Marsh et al. (2018b)	Australia	RCT (50)	MED; SURG
Pandurangadu et al. (2018)	USA	Prospective (86)	ED
Rickard et al. (2018)	Australia	RCT (422)	MED; SURG
Bahl et al. (2019)	USA	RCT (37)	ED
Ghali et al. (2019)	Tunisia	Prospective (210)	Cardiology
Penoyer et al. (2019)	USA	Prospective (352)	MED; neurosurgical
Wei et al. (2019)	China	Prospective (1477)	General hospital
Keogh et al. (2020)	Australia	RCT (306)	MED; SURG
Pérez-Granda et al. (2020)	Spain	RCT (192)	
Saliba et al. (2020)	Spain; Italy	Prospective (3853)	Trauma; MED; SURG
Takahashi et al. (2020)	Japan	Prospective (422)	NR
Bahl et al. (2021a)	USA	RCT (174)	ED
Bahl et al. (2021b)	USA	Prospective (62)	ED
Blanco-Mavillard et al. (2021)	Spain	RCT (2330)	MED; SURG; oncology
Buetti et al. (2021)	Switzerland	Retrospective (412,631)	General hospital
Guenezan et al. (2021)	France	RCT (495)	ED
Larsen et al. (2021)	Australia	Prospective (396)	Haematology; oncology
Li et al. (2021)	China	RCT (2278)	MED; SURG
Olivier et al. (2021)	USA	Retrospective (737)	Critical care; step down; oncology
Ozger et al. (2021)	Turkey	Prospective (544)	IDD
Shintani et al. (2022)	Japan	Prospective (280)	Haematology; oncology

USA: United States of America; UK: United Kingdom; RCT: randomised controlled trial; MED: medical ward/unit; SURG: surgical ward/unit; OPD: outpatient department; CCU: cardiac coronary unit; ICU: intensive care unit; OT: operating theatre; IDD: infectious diseases department; ED: emergency department; OB: obstetrics; GYN: gynaecology; NR: not reported.

Mee-Marquet et al., 2007; Mahmoud et al., 2017; Holder et al., 2017; Barker et al., 2004; Bausone-Gazda et al., 2010; Bertolino et al., 2012; Bridey et al., 2018; Forni et al., 2012; Günther et al., 2016; Gupta et al., 2007; Haddad et al., 2006; Niesen et al., 2003; Nishanth et al., 2009; Panadero et al., 2002; Abbas et al., 2007; Atay et al., 2018; Benaya et al., 2015; Bolton, 2010; Bonnici, 2012; Boyce and Yee, 2012; Catney et al., 2001; Cicolini et al., 2009; Cicolini et al., 2014; Curran et al., 2000; Datar et al., 2018; Erdogan and Denat, 2016; Fujita et al., 2006; Gallant and Schultz, 2006; Goransson and Johansson, 2012; Gregg et al., 2010; Grune et al., 2004; Hasselberg et al., 2010; Hirschmann et al., 2001; Johansson et al., 2008; Karadağ and Görgülü, 2000; Kaur et al., 2011; Lanbeck et al., 2002; Meng et al., 2018; Nassaji-Zavareh and Ghorbani, 2007; Palese et al., 2016; Pasalioglu and Kaya, 2014; Rojas-Sánchez et al., 2015; Ronen et al., 2017; Saini et al., 2011; Sarafzadeh et al., 2012; Salles et al., 2007; Singh et al., 2008; Tanabe et al., 2016; Urbanetto et al., 2017; Urbanetto et al., 2016; Uslusoy and Mete, 2008; White, 2001; Zarate et al., 2008; Ascoli et al., 2012; Simoes et al., 2022; Maunoury et al., 2022), reported vascular access procedures (Benham et al., 2007; Ortiz et al., 2014; Chukhraev et al., 2000), or were secondary analyses/commentaries on data already included (Danski et al., 2015; Lanbeck et al., 2003; Myrianthefs et al., 2005). Additional information was provided from authors for eight studies (Webster et al., 2007; Webster et al., 2008; Rickard et al., 2010; Rickard et al., 2012; Van Donk et al., 2009; Keogh et al., 2016; Bugden et al., 2016; Marsh et al., 2018a).

A total of 41 cohort studies (37 prospective and four retrospective) and 28 randomised controlled trials were included (478,586 participants). Nineteen studies were from Europe (Vandenbos et al., 2003; Periard et al., 2008; Martínez et al., 2009; Chico-Padrón et al., 2011; Elia et al., 2012; Mestre Roca et al., 2012; Salgueiro-Oliveira et al., 2012; Mestre et al., 2013; González López et al., 2014; Miliani et al., 2017; Cornely et al., 2002; Creamer et al., 2002; Dillon et al., 2008; Blanco-Mavillard et al., 2021; Buetti et al., 2021; Guenezan et al., 2021; Guihard et al., 2018; Pérez-Granda et al., 2020; Saliba et al., 2020), 15 from North America (Palefski and Stoddard, 2001; Royer, 2003; Schears, 2006; McNeill et al., 2009; Adhikari et al., 2010; Dargin et al., 2010; Fields et al., 2012; Fakih et al., 2012; Anderson, 2016; Bahl et al., 2019; Pandurangadu et al., 2018; Bahl et al., 2021a; Bahl et al., 2021b; Olivier et al., 2021; Penoyer et al., 2019), 16 from Asia (Fujita and Namiki, 2008; Lee et al., 2009; Abolfotouh et al., 2014; Zhu et al., 2016; Murayama et al., 2017; Takahashi et al., 2017; Tan et al., 2017; Xu et al., 2017a; Tan et al., 2016; Xu et al., 2017b; Wei et al., 2019; Takahashi et al., 2020; Shintani et al., 2022; Ozger et al., 2021; Li et al.,

Table 2
Proportion and incidence rates of peripheral intravenous catheter failure and infection in included studies.

Event	Proportion of events reported					IR of events reported					
	N	PIVCs	Outcomes	Pooled (%)	95 % CI	*N*	Catheter-days	Outcomes	Pooled IR	Denominator (catheter-days)	95 % CI
CABSI	38	437,255	78	0.028*	0.009–0.081	20	1,545,195	68	4.40	100,000	3.47–5.58
Local infection	30	22,403	236	0.150*	0.047–0.479	16	75,242	49	65.1	100,000	49.2–86.2
PIVC failure	53	46,870	16,108	36.4‡	31.7–41.3	19	78,891	3484	4.42	100	4.27–4.57

CI = confidence interval; IR = incidence rate; *N* = number of studies; % = per cent (per hundred); PIVC = peripherally inserted venous catheter; CABSI = catheter-associated bloodstream infection; heterogeneity of studies: *low (0–33 %), ‡high (64–100 %).

2021; Wang et al., 2015), two from South America (Danski et al., 2016; Enes et al., 2016), 16 from Australia (Webster et al., 2007; Webster et al., 2008; Rickard et al., 2010; Rickard et al., 2012; Van Donk et al., 2009; Keogh et al., 2016; Bugden et al., 2016; Marsh et al., 2018a; Taylor, 2003; Marsh et al., 2015b; Rickard et al., 2018; Carr et al., 2018; Marsh et al., 2018b; Marsh et al., 2018c; Larsen et al., 2021; Keogh et al., 2020), and one from Africa (Ghali et al., 2019). Participants were most frequently from medical/surgical departments, but multiple specialties were also represented. Table 1 contains further study characteristics. The intervention and control groups of two randomised controlled trials were combined for analysis as both practices were recommended in international guidelines (standard practice) (Keogh et al., 2016; Tan et al., 2016).

Reporting quality in 41 included cohort studies was mixed. Outcome measures were defined in all but five studies (Vandenbos et al., 2003; Royer, 2003; Schears, 2006; Anderson, 2016; Ghali et al., 2019), and a clear objective or question was lacking in three studies (Mestre et al.,

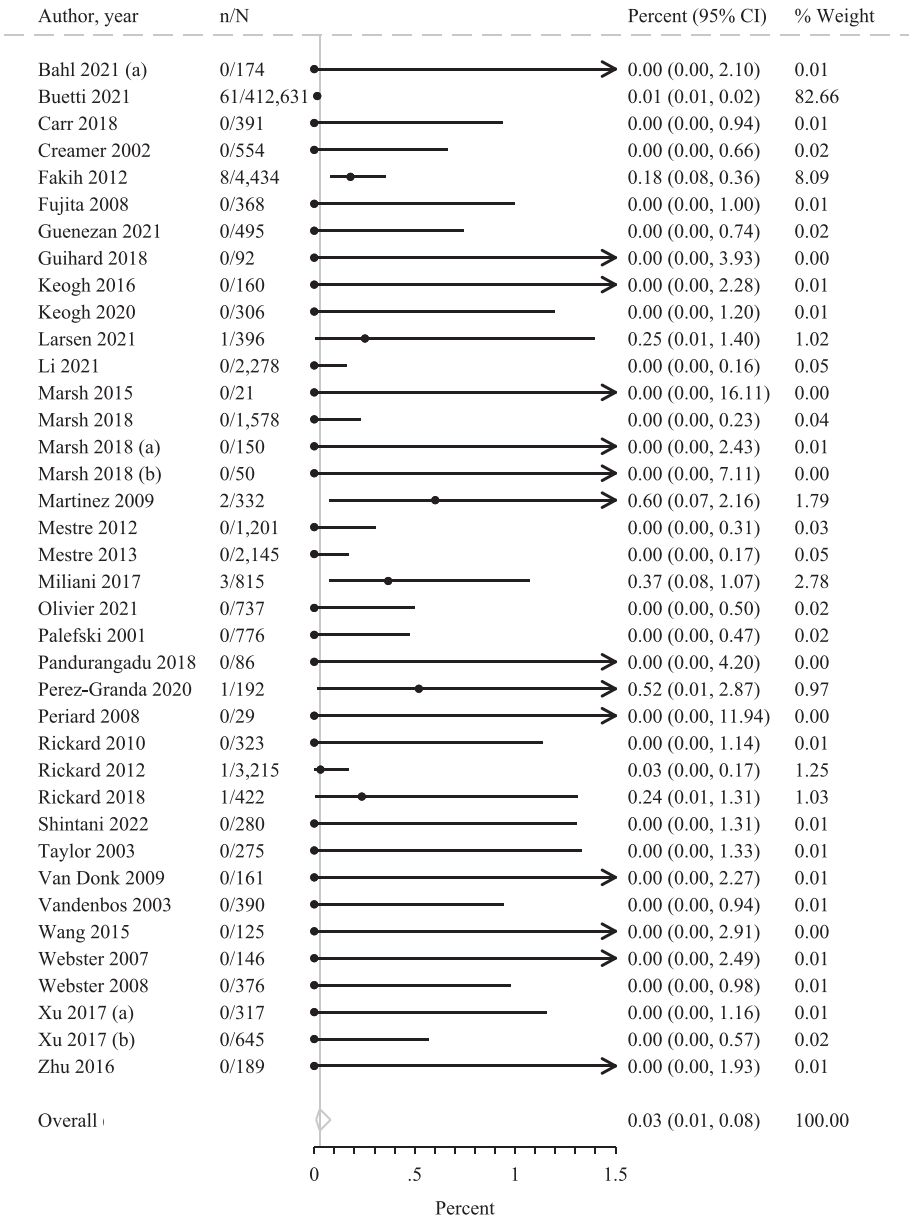

Fig. 2. Proportion of catheter associated bloodstream infections.

2013; Fujita and Namiki, 2008; Ozger et al., 2021). Only nine studies provided sample size justification (Marsh et al., 2018a; Dargin et al., 2010; Fields et al., 2012; Fakih et al., 2012; Penoyer et al., 2019; Abolfotouh et al., 2014; Zhu et al., 2016; Wei et al., 2019; Larsen et al., 2021). The majority of randomised controlled trials had low risk of bias for random sequence generation (23/28, 82 %), and 17/28 (61 %) clearly described the method of allocation concealment (Supplementary Table 2). Although blinding of participants and personnel was not possible, we did not consider this a potential bias as we do not think it would have influenced the outcome measure. Blinding of outcome assessors was poorly reported, with minimal or no information reported in 22/28 (79 %) trials.

Six studies did not report a precise definition for catheter-associated bloodstream infections (Vandenbroucke et al., 2014; Pandurangadu et al., 2018; Fujita and Namiki, 2008; Zhu et al., 2016; Carr et al., 2018; Ghali et al., 2019), four used clinical findings with or without culture data (Periard et al., 2008; Martínez et al., 2009; Miliani et al., 2017; Palefski and Stoddard, 2001), and 19 used more rigorous Centers for Disease Control and Prevention, National Healthcare Safety Network/National Nosocomial Infections Surveillance System definitions (Webster et al., 2007; Webster et al., 2008; Rickard et al., 2010; Rickard et al., 2012; Marsh et al., 2018a; Mestre Roca et al., 2012; Mestre et al., 2013; Creamer et al., 2002; Fakih et al., 2012; Bahl et al., 2021b; Olivier et al., 2021; Xu et al., 2017a; Xu et al., 2017b; Shintani et al., 2022; Taylor, 2003; Marsh et al., 2015b; Rickard et al., 2018; Larsen et al., 2021; Keogh et al., 2020). Local infection was not defined in three studies (Vandenbos et al., 2003; Cornely et al., 2002; Ghali et al., 2019), but the remaining studies used definitions consistent with National Healthcare Safety Network/National Nosocomial Infections Surveillance System definitions.

After pooling, the proportion of catheter-associated bloodstream infections was 0.028 % (38 studies, CI: 0.009–0.081; $I^2 = 3$ %, $P < .001$) or 4.40 catheter-associated bloodstream infections per 100,000 catheter-days (20 studies, 95 % CI: 3.47–5.58) (Table 2, Fig. 2). Sensitivity analyses comparing prospective and retrospective studies found no difference ($P = .380$) (Supplementary Table 3). We were unable to undertake sensitivity/subgroup analyses for studies with small samples, from the emergency setting or developing economies, due to zero reported infections in these studies.

The pooled proportion of peripheral intravenous catheters in which the patient experienced a local infection was 0.150 % (30 studies; 95 % CI: 0.047–0.479; $I^2 = 9$ %) and 65.1 per 100,000 catheter-days (16 studies; 95 % CI: 49.2–86.2) (Table 2). There was no statistically significant difference in the proportions of local infections between emergency department placed catheters versus other departments, countries with developed versus developing economies, and prospective compared to retrospective studies (Supplementary Table 3). Zero infection incidence in the six studies with small sample sizes precluded this sensitivity analysis.

Peripheral intravenous catheter failure was defined in 52/53 studies; 28 studies reported this outcome as a composite of complications which at a minimum included: phlebitis, infiltration, occlusion, and/or dislodgement (Webster et al., 2007; Rickard et al., 2010; Rickard et al., 2012; Keogh et al., 2016; Marsh et al., 2018a; Elia et al., 2012; González López et al., 2014; Miliani et al., 2017; Blanco-Mavillard et al., 2021; Guenezan et al., 2021; Saliba et al., 2020; Palefski and Stoddard, 2001; Royer, 2003; McNeill et al., 2009; Dargin et al., 2010; Anderson, 2016; Fujita and Namiki, 2008; Abolfotouh et al., 2014; Tan et al., 2017; Wei et al., 2019; Takahashi et al., 2020; Li et al., 2021; Danski et al., 2016; Marsh et al., 2015b; Carr et al., 2018; Marsh et al., 2018b; Larsen et al., 2021; Keogh et al., 2020). Other studies (n = 24) used a different description or included less complications to define failure, and one study did not provide a definition (Adhikari et al., 2010).

Fifty-three studies reported the incidence of peripheral intravenous catheter failure (Supplementary Fig. 1). The overall incidence was 36.4 % (95 % CI: 31.7–41.3; $I^2 = 94$ %, $P < .001$) and the overall incidence rate (IR) was 4.42 per 100 catheter days (78,891 catheter days; 19 studies; 95 % CI: 4.27–4.57) (Table 2). The proportion of failure per region was lowest in North America at 32 % (95 % CI: 25–41) and highest in South America at 63 % (95 % CI: 56–69) (Supplementary Fig. 2).

The bubble plot of peripheral intravenous catheter failure by year of publication (Fig. 3) does not show evidence for a trend. When the year was regressed on the proportion of peripheral intravenous catheter failures, the results were not statistically significant, indicating that the variability in failures did not appreciably change over time. Subgroup and sensitivity analyses also found no difference in peripheral intravenous catheter failure for those inserted in an emergency department compared to other clinical settings, developed versus developing economies, small versus large studies and retrospective versus prospective studies.

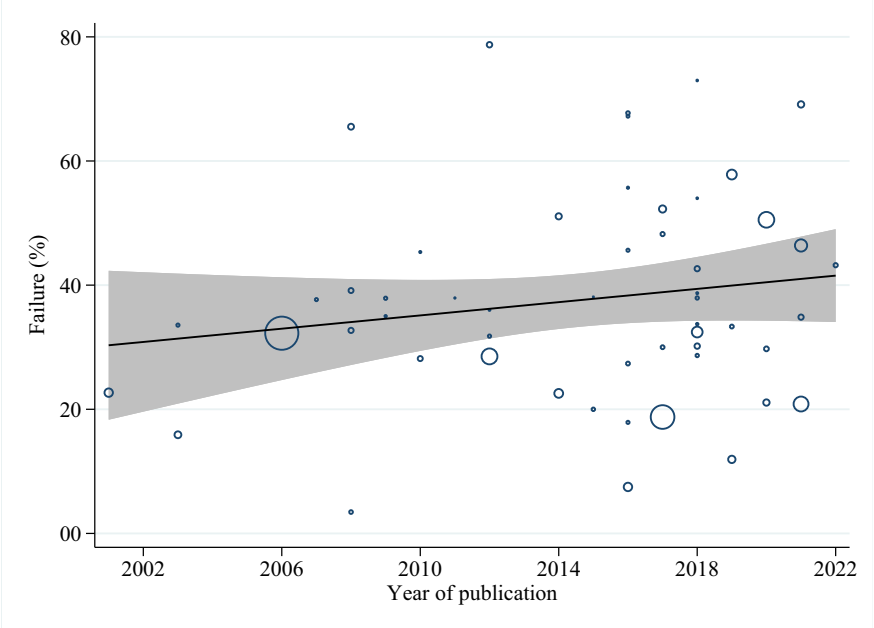

Fig. 3. Bubble plot of peripheral intravenous catheter failure.

4. Discussion

This is the first large-scale systematic review and meta-analysis in adults to address peripheral intravenous catheter-related infection and all-cause failure, which are preventable causes of patient harm. This is important as peripheral intravenous catheters are the most ubiquitous invasive medical device and contribute substantially to nursing workloads. Ideally, catheters should remain complication free for the duration of therapy, but our review shows that approximately one in three (36 %) fail during treatment, and this has not improved over time despite advancements in peripheral intravenous catheter technology (Rickard et al., 2023; Matthews et al., 2023). Rather than failure, the focus of vascular access device attention in recent decades has centred on improving bloodstream infection rates associated with central venous access devices (Tatsuno et al., 2019). Little consideration has been given to infections caused by peripheral intravenous catheters.

This review has found that approximately one in 5606 peripheral intravenous catheters developed a catheter-associated bloodstream infection. This is concerning considering the enormous volume of peripheral intravenous catheters used globally, potentially making peripheral intravenous catheter-associated bloodstream infection rates comparable to those associated with central venous access devices (Blauw et al., 2019; Sato et al., 2017; Capdevila et al., 2016). Moreover, whilst gold standard central-line associated bloodstream infection criteria simply require the presence of a central venous access device for ≥2 calendar days (in the absence of infection at another site), peripheral intravenous catheter-associated bloodstream infections require site documentation of purulence or positive catheter tip culture (National Healthcare Safety Network, 2023). Patients with catheter-associated bloodstream infections often lack the obvious signs and symptoms (e.g., redness, pain, pus) at the insertion site needed to prompt catheter tip culture, likely causing an underestimation of catheter-associated bloodstream infection rates (Sato et al., 2017).

Whilst this systematic review did not individually report *S. aureus* peripheral intravenous catheter-associated bloodstream infections, *S. aureus* is the most frequently isolated organism associated with such infections (Saliba et al., 2018; Guembe et al., 2017). Correspondingly, peripheral intravenous catheters are also one of the most common sources of hospital-onset *S. aureus* (Blauw et al., 2019; Young et al., 2023). Rates of *S. aureus* bacteraemia are a common (publicly-reported) surrogate measure of quality in tertiary healthcare, due to the high attributable mortality and prevalence (Poirier et al., 2022). Zingg et al. (2023) recently reported pooled 30-day mortality for patients with a peripheral intravenous catheter blood stream infection ranged from 11 % to 13.2 %, however if the causative organism was *S. aureus*, mortality was reported as high as 27 % and 35.8 % (Sato et al., 2017; Pujol et al., 2007). Cost implications associated with antimicrobial treatment are also considerable for *S. aureus* peripheral intravenous catheter-associated bloodstream infections, reported to take almost twice as long to treat as non-*S. aureus* infections (43 vs 27 days) (Guembe et al., 2017).

The catheter-associated bloodstream infection incident rate in this review was 0.044 per 1000 catheter-days, which is substantially lower than an earlier review of 10 studies that found a rate of 0.5 per 1000 catheter days (Maki et al., 2006). This may reflect our focus on studies published between 2000 and 2022, whereas Maki et al. (2006) covered 1966 to 2005 and included steel needles and peripheral intravenous catheters placed by venous cutdown (both outdated products and practices). In this analysis, the catheter-associated bloodstream infection proportion (0.03 %) was also lower than the rate (0.18 %) reported in a more recent review of 14 articles (1980 to 2017) where a majority of data were drawn from a French surveillance report (Mermel, 2017); in contrast, our review excluded audit data and required studies with a known denominator. Our review highlights that infection is an under-assessed source of catheter failure with catheter-associated bloodstream infections reported in only 38 of 69 included studies.

Local infections occurred in one in 236 peripheral intravenous catheters with a pooled proportion of 0.15 %, which was lower than results reported in a recent literature review (0.1 to 5.1 %) (Helm et al., 2015). Whilst early detection of local infection is important to prevent progression to catheter-associated bloodstream infections, our review found that this was an under-reported outcome, only measured in 30 of 69 studies.

Our sensitivity analyses found no effect of study size or retrospective/prospective design, supporting the validity of our inclusion criteria. Local infection and failure outcomes were not significantly higher for catheters inserted in the emergency department, and no bloodstream infections reported in this setting. However, with <0.5 % of our sample inserted in the emergency department, we are unable to rule out increased associated risk. Similarly, we observed non-significantly different outcomes in countries with developed versus developing economies, but the latter constituted only 2 % of the total sample. More information is needed about infection prevention of peripheral intravenous catheters in low resourced countries (Alexandrou et al., 2015), with overall healthcare-associated infection risk reported as two to three-fold that of high resource health systems (Allegranzi et al., 2011).

Our results highlight a need to reduce peripheral intravenous catheter infection and failure through a multi-faceted approach. Clinically, we see three key local opportunities to do so: (1) education strategies aimed at reducing inconsistency in insertion and maintenance practices; (2) preventing multiple catheter replacements and subsequently preserving patients' vessel health by individual patient assessments that ensure the most appropriate vascular access device is inserted (Hallam et al., 2016); and (3) early removal of idle catheters prompted by the use of a validated clinical decision tool (Ray-Barruel et al., 2020) In addition, system-wide strategies should be implemented similar to the notification of central venous access device infections which has informed the creation and implementation of best practices to inform central venous access device insertion and care, leading to a reduction in infections (Lim et al., 2019). Peripheral intravenous catheter infection was recognised in the top ten patient safety concerns for 2019 and Australia was recently the first known country to release a national Clinical Care Standard for peripheral intravenous catheter safety (Brief, 2019; Australina Commission on Saftery and Quality in Health Care, 2021). Currently some countries use *S. aureus* bloodstream infections as a clinical indicator to reflect the safe, quality use of peripheral intravenous catheters (Australian Institute of Health and Welfare, 2020). Our review supports the need to expand this focus to include monitoring of all vascular access device-related bloodstream infections. The development of peripheral intravenous catheter registries with standardised definitions for self-monitoring should be implemented, allowing for benchmarking within and between institutions (Schults et al., 2020).

4.1. Limitations

Although we conducted a comprehensive literature search, some studies may have been missed, and our search limits to English language and publications after the year 2000 may have impacted our findings. As catheter days were not included in all studies, the meta-analyses of rates were affected. The heterogeneity of the study populations may preclude generalisability to specific patient subgroups but does provide a good reflection of peripheral intravenous catheter issues at the system level, and subgroup analyses explored potential at-risk subgroups. Future systematic reviews should consider a sub-group analysis comparing short versus long peripheral intravenous catheters. Nonetheless, this review reflects modern peripheral intravenous catheter materials and practices, provides the most comprehensive review to date of peripheral intravenous catheter infection and failure, including the first meta-analysis of local infections, and sets a new benchmark for catheter-associated bloodstream infection rates in peripheral intravenous catheters.

5. Conclusions

With over one-third of peripheral intravenous catheters failing, there is a clear need for a more systematic and planned approach to not only insertion but also post-insertion management with an emphasis on monitoring peripheral intravenous catheter related infections. In addition, future research exploring peripheral intravenous catheter infection risk factors is needed to aid in the development of infection prevention strategies to inform clinical decision-making. The potential benefits for patients and health services are substantial if peripheral intravenous catheter infections and failures can be reduced.

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Nicole Marsh: Writing – review & editing, Writing – original draft, Validation, Methodology, Formal analysis, Data curation, Conceptualization. **Emily N. Larsen:** Writing – review & editing, Validation, Formal analysis, Data curation. **Amanda J. Ullman:** Writing – review & editing, Validation, Methodology, Data curation. **Gabor Mihala:** Writing – review & editing, Methodology, Formal analysis. **Marie Cooke:** Writing – review & editing, Methodology, Conceptualization. **Vineet Chopra:** Writing – review & editing, Methodology. **Gillian Ray-Barruel:** Writing – review & editing, Validation, Data curation. **Claire M. Rickard:** Writing – review & editing, Methodology, Conceptualization.

Data availability

The data that support the findings of this study are available on request made to the corresponding author.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

NM: Griffith University and The University of Queensland have received on her behalf investigator-initiated grants from Cardinal Health and Eloquest, and consultancy payments from 3M and Becton Dickinson for expert advice/educational sessions, unrelated to this work.
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