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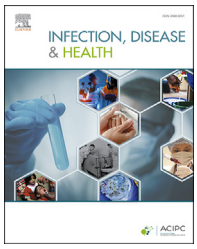

Review

Peripheral intravenous catheter material and design to reduce device failure: A systematic review and meta-analysis

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Abstract *Background:* Patients require vascular access for medical treatments, diagnostic procedures and symptom management. Current failure rates of peripheral intravascular catheters (PIVCs) are unacceptably high (40–50%). This systematic review aimed to determine the effect of different PIVC materials and designs on the incidence of PIVC failure.
Methods: A systematic search was conducted in November 2022 using CINAHL, PubMed, EMBASE and Cochrane Central Register of Controlled Trials databases. Randomised controlled trials that compared PIVC novel PIVC material/design and standard material/design were included. The primary outcome was all causes of PIVC failure, any reason for device removal due to cessation of device function; and secondary outcomes included individual PIVC complications and infection (local or systemic), and dwell times. Quality appraisal was conducted using the Cochrane risk of bias tool. A meta-analysis was performed using random effects model.
Results: Seven randomised controlled trials were eligible for inclusion. In meta-analysis, the impact of material and design on PIVC failure in the studies favoured the intervention arms (RR 0.71, 95% CI 0.57–0.89), however there was substantial heterogeneity (I^2 = 81%, 95% CI

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61−91%). Through subgroup analyses, a significant difference on PIVC failure favoured the closed system over the open system (RR 0.85, 95% CI 0.73 to 0.99; I^2 = 23%, 95% CI 0−90%). *Conclusion:* Catheter material and design can impact PIVC outcome. Conclusive recommendations are limited due to the small number of studies and inconsistent reporting of clinical outcomes. Further rigorous research of PIVC types is necessary to improve clinical practice and device selection pathways should reflect the resulting evidence.

Highlights

- Peripheral intravenous catheters (PIVC) are the most common invasive medical device.
- PIVC failure remains unacceptably high, negatively impacting the patient outcomes.
- PIVCs with novel material and design reduced PIVC failure compared to standard care.
- More investment, innovation and evaluation of PIVC material and design is needed.
- Clinician understanding of application in practice could inform future PIVC innovation.

Introduction

A peripheral intravenous catheter (PIVC) is a small flexible tube inserted into a peripheral vein for administration of fluids, medicines, blood or diagnostic purposes [1,2]. The first reported device, made from a feather quill, was in the 1600s [3,4]. By the 1830s, "small silver tubes" were used [5] and following this, a multi-use steel needle with an internal stylet was developed [4]. Complications such as phlebitis and dislodgement were reported [4,6] most likely due to the hard inflexible steel material of the PIVC. In the mid-1900s, PIVCs consisted of plastic tubing (polyvinyl chloride) [4,6] that encased a sterling silver needle [7] and progressed over the years to softer and smoother materials to reduce vein irritation such as polyethylene [6], teflon, polypropylene and more recently, polyurethane [4]. Other recent innovations to improve performance of the modern catheter include: closed systems [8,9]; integrated sets [4,8] and wing features [9]. Although advancements have been made in catheter material and design, complication rates including infection remain problematic [10−12].

Though the infection rate is reported to be relatively low in incidence, the overall volume of devices used (~2 billion/year globally) [13] make it a significant clinical problem. Furthermore, the infection source of PIVC- BSI is often *Staphylococcus aureus*, which is associated with significant morbidity and mortality and increased health burden [10,14]. PIVCs are also susceptible to failure from other complications such as phlebitis, infiltration, dislodgement and occlusion [12,15]. Unacceptable levels of PIVC failure (up to 50%) have been reported [16,17] requiring unplanned removal of the PIVC and additional cannulation attempts [18,19]. To improve patients' experiences, reducing PIVC failure and optimising vessel health preservation is a high priority for healthcare professionals. Though advances in PIVC development have been made over the years, comprehensive understanding of the optimal PIVC design is unknown and largely untested. The aim of this systematic review and meta-analysis is to determine the effect of peripheral intravenous catheter (PIVC) material and design on reducing incidence of device failure.

Methods

This systematic review and meta-analysis was guided by the Cochrane Method [20] and reported the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [21]. It is registered on the PROSPERO website (CRD42021282574).

Search methods

A comprehensive search was conducted for studies between January 2010 and 25th November 2022 in the Cochrane Central Register of Controlled Trials, PubMed, CINAHL and EMBASE (OVID) databases. The review was limited to studies written in English and conducted since the year 2010 to reflect contemporary practice. The review team developed search terms with the assistance of a health librarian and MeSH and textual terms were used such as those related to "peripheral intravenous catheter", "catheter-related infections" or "equipment failure" and Boolean logic (AND, OR). See Table S1 for PubMed example of final search conducted.

Eligibility criteria

Randomized controlled trials or clinical controlled trials (adult and paediatric) that reported PIVC material and/or design and PIVC failure in a hospital or community setting were eligible for inclusion. The comparator or control was standard care at that point in time and included catheters with different features (materials and/or designs) to the intervention. Studies of other types of vascular access devices (e.g., central venous catheters), systematic reviews, qualitative studies, case studies and cohort studies were excluded.

Outcomes

The primary outcome of this review was PIVC failure defined as any reason for unplanned device removal (including a

composite measure of PIVC failure and individual PIVC complications) due to cessation of device function as described by the trial investigator. The secondary outcomes included: subtypes of device failure (individual PIVC complications) and device dwell time (time from insertion to removal). The PIVC complications were defined as phlebitis (inflammation of the vein as determined by trial investigator), dislodgement (movement of catheter out of the vein); infiltration/extravasation (movement of fluids/vesicants into the tissues with or without leakage); occlusion (blockage of lumen); and infection, (catheter related as determined by pathology results or site infection determined by local site redness) [12].

Study selection and data extraction

All identified citations were collated and uploaded into bibliographic software management system (EndNote X9) and duplicates removed. One author (RM) screened the titles and abstracts against inclusion and exclusion criteria and a sample of 20% was checked for accuracy by a second author (NG) [22]. Full text of the potentially eligible studies was assessed for eligibility by two authors (RM, NG). Any disagreements were resolved by discussion with a third reviewer (NM). Data extraction of primary and secondary outcomes for evidence synthesis was carried out independently by two authors (RM, NG) using a purpose-built data extraction form. Where necessary, study authors were contacted for clarification of PIVC type.

Statistical analysis

Quantitative data was entered into RevMan 5.4, and data pooled using meta-analysis with exact confidence intervals (CIs) and risk ratios (RRs) displayed in forest plots. Clinical, methodological, and statistical heterogeneity was considered. Heterogeneity was assessed by Q-statistic and corresponding p-value, and the I^2 statistic and corresponding 95% confidence interval [23]. Heterogeneity was considered low, moderate, substantial and considerable if I^2 ranged between $<$40%; 30–60%; 50–90% and $>$75% respectively [24]. Potential heterogeneity was explored through subgroup analyses, and due to predicted clinical heterogeneity in estimating the intervention effect, a random effects model was used for meta-analysis. The unit of analysis for PIVC failure and PIVC complications was by device not participants. For the studies that did not report PIVC failure, but reported PIVC complications, PIVC failure composite data was calculated from manually adding data from the outcomes that led to PIVC removal [25].

Design and material aspects were analysed in separate meta-analysis where the newer type of design or material considered the 'intervention' and the previous type of design or material considered the 'control'.

Risk of bias (quality) assessment

The Cochrane risk of bias tool [26] was used and assessed the following domains, selection, performance, detection, attrition, and reporting bias. Two authors independently assessed studies for risk of bias (RM, NG). Disagreements between the review authors were resolved by discussion with a third reviewer (NM).

Results

Study selection

The search of databases identified 1142 articles published between January 2010 and November 2022. After including an additional study (pre-printed at time of submission and identified in a published protocol) and removing 400 duplicates, 742 articles were selected for title and abstract screening. From this screening, 19 full texts were assessed for eligibility and seven were included in the quantitative synthesis (see Fig. S1).

Characteristics of included studies

The seven studies included in this review were randomised controlled trials (RCTs) and reported on 3724 hospitalised adults and 4281 PIVCs. Five studies reported their sample population from medical and/or surgical wards [27–31]. The age of participants ranged from 18 years to 90 years, with a mean age of 64 years. Six studies reported patient gender, and most participants were male (n = 2030; 55%). The studies were conducted between the years 2008 and 2019 in various countries including Brazil [32], Spain [29], Turkey [30], Australia [31], Japan [33] and two from North America [27,28].

Two studies compared PIVC designs such as integrated and non-integrated sets (built-in extension set and external extension set) [31,33], three studies compared closed and open systems (needleless and non-needleless) [28,29,32], one study compared built-in stabilisation (winged) devices and external stabilisation devices [27] and the remaining study compared PIVC material, vialon and teflon [30]. Most PIVCs had multiple design aspects. BD Nexiva™ (a winged vialon PIVC in a closed integrated system) was the most common PIVC used in four studies as the intervention. Various other brands and designs were used as standard care. A corresponding author in one study [32] was contacted for clarification of PIVC design. From the results, four subgroups were used to guide the data analysis for catheter material and design: vialon and teflon material, integrated and non-integrated set, closed and open system, and winged and non-winged PIVC design (Table 1 and Table S2).

Three studies reported intention to treat (ITT) and this data was chosen for analysis. For the remaining four studies, the reported data was used for analysis as no protocol violation was reported.

Quality assessment

Out of the seven RCTs appraised for quality, only one study [31] demonstrated a low risk of bias overall (see Table S3). Three studies reported difficulties of blinding [27,29,31], due the visual nature and obvious differences of the PIVC devices therefore these were considered to be low risk for performance and detections bias and unlikely to influence

Table 1 Descriptive table of seven randomised controlled trials included in quantitative synthesis review.

Study ID	Country	Age, Baseline y, M(SD)		Gender Baseline female (%)		Population and PIVC ITT	No of PIVCs and brand per arm	Material and design subgroups from studies used for analysis							
		Inter-vention	Control	Inter-vention	Control			Vialon	Teflon	Integrated	Non-integrated	Closed	Open	Winged	Non-winged
Bausone-Gazda et al. (2010)	USA	60 (16.53)	60.8 (17.12)	84 (56)	92 (61)	302 med/surg inpatients ≥18 years (302 PIVCs)	Intervention (n = 150) BD Nexiva™	✓		✓		✓		✓	
							Control (n = 152) B. Braun Introcan Safety®		✓		✓		✓		✓
Danski et al. (2016)	Brazil	90 (18.05)	79 (16.55)	48 (53.3)	34 (43)	169 inpatients ≥18 years (169 PIVCs)	Intervention (n = 90) Complete safety PIVC	X[a]		✓		✓		✓	
							Control (n = 79) Short flexible PIVC				✓		✓		✓
Galang (20)	USA	61.9 (17.59)		162 (56.8)		285 inpatients ≥18 years (285 PIVCs)	Arm B. Intervention (n = 104) Closed system, integrated set	NR		✓		✓		X[g]	
							Arm C. Intervention (n = 107) Closed winged, integrated set			✓		✓		✓	
							Arm A Control (n = 74) Non-integrated PIVC				✓		✓		✓
González López et al. (2014).	Spain	71.5 (NR)		NR		642 med/surg inpatients ≥18 years (1183 PIVCs)	Intervention (n = 582[h]) BD Nexiva™	✓		✓		✓		X[b]	
							Control (n = 599[h]) B. Braun Vasocan® safety		✓		✓		✓		
Kuş and Büyükyılmaz (2020)	Turkey	43.6 (10.55)	43.2 (10.66)	60 (57.7)	59 (56.7)	208 surg inpatients ≥18 years (208 PIVCs)	Intervention (n = 104) BD Insteye™ Autoguard™	✓		X[c]		X[d]		X[b]	
							Control (n = 104) BD Venflon™		✓						
Rickard et al. (2022)	Australia	60.5 (17.4)	59.7 (17.3)	354 (40)	351 (40)	1759 med/surg inpatients ≥18 years (1710 PIVCs)	Intervention (n = 862) BD Nexiva™	✓		✓		X[e]		X[b]	
							Control (n = 848) B. Braun Introcan Safety® 3		✓		✓				
Tamura et al. (2014)	Japan	71.8 (15.0)	70 (15.1)	86 (44.3)	71 (43)	359 inpatients ≥20 years (358 PIVCs)	Intervention (n = 193) BD Nexiva™	X[f]		✓		X[e]		✓	
							Control (n = 165) Medikit Co., Ltd.				✓				✓

Note: Abbreviations: ext, extension; RCT, randomised controlled trial; med, medical; surg, surgical; NR, not reported; X, subgroup not able to be used for analysis.

[a] silicon versus polyurethane.

[b] Both winged design.

[c] Both non-integrated.

[d] Arms were both open systems.

[e] Arms both closed systems.

[f] Arms both polyurethane materials.

[g] Arm A (control) and C (intervention) compared for winged and non-winged subgroup.

[h] Denominators for each arm were not reported by study author. These were calculated by review author and statistician using reported percentages in study and may not sum reported total.

the results [34]. The other four studies did not report blinding, so the risk of bias in these domains was considered unclear. There was a high risk of selective reporting bias in four of the studies due to lack of trial registration [27,28,30,33].

Primary outcome

The data from the outcomes of the study are reported in Table 2.

PIVC failure

Data was pooled from the seven studies (n = 4213 individuals) for meta-analysis to evaluate differences between intervention and standard care on PIVC failure. The analysis of the seven studies found a statistically significant difference of the effect of the intervention (RR 0.71, 95% CI 0.56–0.89), however there was substantial heterogeneity (I^2 = 81%, 95% CI 61%–91%) (see Fig. 1).

The heterogeneity was explored in subgroup analysis for the different types of PIVCs – vialon versus teflon (n = 3401), integrated versus non-integrated (n = 4005), closed versus open system (n = 1937) and winged versus non-winged systems (n = 1010). The effect of the closed system on PIVC failure was found to be significant (RR 0.85, 95% CI 0.73–0.99), with low heterogeneity (I^2 = 23%, 95% CI 0–90%) (Fig. 2(c)), meaning the closed system has a 15% less risk of PIVC failure compared to the open system. Significant differences were found to favour the vialon material (RR 0.68, 95% CI 0.52–0.91; I^2 = 86%, 95% CI 67–94%) in Fig. 2(a), and integrated set (RR 0.82, 95% CI 0.69–0.97; I^2 = 63%, 95% CI 9–85%) in Fig. 2(b) though heterogeneity for both was substantial. There was no significant difference on PIVC failure between the winged and non-winged PIVC groups (RR 0.74, 95% CI 0.48–1.14) with substantial heterogeneity (I^2 = 75%, 95% CI 29–91%) as seen in Fig. 2(d).

Secondary outcomes

Dwell time

Four studies measured dwell times as time from insertion to time of removal due to catheter failure (Table 2). Compared to standard care, significantly higher dwell times were reported in the intervention arms by González López and colleagues [29] (p = 0.016, median), Kuş and Büyükyilmaz [30] ($p \leq 0.001$, median) and Rickard and colleagues [31] ($p \leq 0.05$, mean difference). In contrast, Galang [28] reported a longer median dwell time with standard care than the intervention however the result was not significant (p=0.38). Meta-analyses were not performed to estimate an overall effect on dwell times due to reporting of potentially non-parametric distribution in the studies.

Infection

Two studies reported catheter related infections [29,31]. Rickard and colleagues [31] reported zero cases of catheter related infection in both arms. González López and colleagues [29] reported slightly more catheter related infections with the closed system (13/582, 2.5%) than the open system (11/599, 2%). Local site infection was reported by Rickard and colleagues [31] in the control (non-integrated PIVC) group (1/848, 0.1%) (Table 2). It was not possible to do a meta-analysis on infection outcomes due to insufficient data.

PIVC complications by catheter type

The results of these outcomes by catheter type are found in Table S4. Data from the studies was pooled for meta-analysis for PIVC complications and can be found in Figs. S2–S5.

Vialon and teflon material

From meta-analysis of four studies, no significant difference was found between the teflon and vialon groups in any of the following PIVC complications - phlebitis (RR 0.74, 95% CI 0.41–1.34; I^2 = 89%, 95% CI 73–95%), infiltration (RR 0.94, 95% CI 0.73–1.20; I^2 = 46%, 95% CI 0–84%) or occlusion (RR 0.84, 95% CI 0.63–1.12; I^2 = 0%, 95% CI 0–100%). The impact of vialon and teflon material on dislodgement favoured the vialon (RR 0.40, 95% CI 0.08–2.05) however the results were not significant (p=0.27), with substantial heterogeneity (I^2 = 80%, 95% CI 15–95%).

Integrated and non-integrated set

From meta-analysis of six studies, there was no significant difference between the integrated and non-integrated set in phlebitis (RR 0.98, 95% CI 0.67–1.44; I^2 = 60%, 95% CI 1–84%), infiltration (RR 0.87, 95% CI 0.65–1.17; I^2 = 55%, 95% CI 0–82%) or occlusion (RR 0.83, 95% CI 0.64–1.08; I^2 = 0; 95% CI 0–38%). The impact of the integrated and non-integrated set on dislodgement favoured the integrated set (RR 0.49, 95% CI 0.21–1.14), however the results were not significant with substantial heterogeneity (I^2 = 62%, 95% CI 0–87%).

Closed and open system

From meta-analysis of four studies, no significant difference was found between the closed and open systems in phlebitis (RR 1.06, 95% CI 0.44–2.55; I^2 = 72%, 95% CI 20%–90%), infiltration (RR 085, 95% CI 0.71–1.03; I^2 = 0%, 95% CI 0%–79%) and occlusion (RR 0.84, 95% CI 0.59–1.18; I^2 = 0%, 95% CI 0%–92%). The impact of the closed and open system on dislodgement favoured the closed system (RR 0.39, 95% CI 0.07–2.26), however the results were not significant with substantial heterogeneity (I^2 = 76%, 95% CI 0%–95%).

Winged and non-winged PIVC

From meta-analysis of four studies, no significant difference was found between winged and non-winged systems in phlebitis (RR 1.44, 95% CI 0.53–3.87; I^2 = 41, 95% CI 0%–81%), infiltration (RR 0.78, 95% CI 0.44–1.38; I^2 = 53%, 95% CI 0%–85%) and occlusion (RR 0.76, 95% CI 0.40–1.44; I^2 = 0%, 95% CI 0%–96%). The impact of winged and non-winged design on dislodgement, favoured the winged design (RR 0.28, 95% CI 0.06–1.35), though the results were not statistically significant with substantial heterogeneity (I^2 = 67%, 95% CI 0%–90%). One study by Bausone and colleagues [27] used an external stabilization design (external wing) as standard care. To ascertain whether this

Table 2 Primary and secondary outcomes. All reported with PIVC as the unit of measurement.

Author, (year)	Primary Outcome		Secondary Outcome — Incidence of complications, no per arm (%)											
	PIVC failure Incidence of, no per arm (%)		Infection		Phlebitis		Dislodgement		Infiltration		Occlusion		Dwell time hrs, M (SD); M (IQR)	
	Intervention	Control	Intervention	Control	Intervention	Control	Intervention	Control	Intervention	Control	Intervention	Control	Intervention	Control
Bausone-Gazda (2010)	NR	NR	NR	NR	8/150* (5.3)	1/152 (0.7)	2/150* (1.3)	14/152 (9.2)	23/150 (15.3)	35/152 (23.0)	NR	NR	NR[a]	NR[a]
Danski (2016)	50/90 (55.6)	44/79 (55.7)	NR	NR	19/90 (21.1)	12/79 (15.2)	8/90 (8.9)	8/79 (10.1)	11/90 (12.2)	9/79 (11.4)	8/90 (8.9)	11/79 (13.9)	NR[a]	NR[a]
Galang (2020)	27/211[b] (12.8) 16/107[c] [15]	9/74 (12.2) 9/74 (12.2)	NR	NR	0/211[b] (0) 0/107[c] (0)	2/74 (2.7) 2/74 (2.7)	NR	NR	12/211[b] (5.7) 7/107[c] (6.5)	2/74 (2.7) 2/74 (2.7)	11/211[b] (5.2) 7/107[c] (6.5)	3/74 (4.1) 3/74 (4.1)	B, 24; C, 26 (IQR NR)	A, 29 (IQR NR)
González López[f] (2014)	248/582[h]** (42.6)	306/599 (51.6)	13/582[d] (2.2)	11/599[d] (1.8)	70/582[h]** (12.0)	101/599 (16.9)	NR	NR	123/582* (21.1)	151/599 (25.2)	42/582 (7.2)	51/599 (8.5)	79* (IQR: 48.5—141.75)	70.25 (IQR: 44.5—116.92)
Kuş (2020)	NR	NR	NR	NR	17/104*** (16.3)	56/104 (53.8)	NR	NR	NR	NR	NR	NR	113.28*** (±28.8)	98.4 (±22.1)
Rickard (2022)	281/862[g]* (32.6)	300/848 (35.4)	0/862[d,e] (0)	0/848[d] (0) 1/848[e] (0.1)	149/862 (17.3)	146/848 (17.2)	88/862[h]* (10.2)	109/848 (12.9)	82/862 (9.5)	68/848 (8.0)	36/862 (4.2)	43/848 (5.1)	51.6 (IQR 27.0—94.9)	49.8 (IQR 26.1—84.1)
Tamura (2010)	NR	NR	NR	NR	4/193 (2.1)	3/165 (1.8)	0/193** (0)	6/165 (3.6)	13/193*** (6.7)	27/165 (16.4)	3/193 (1.6)	5/165 (3.0)	NR[a]	NR[a]

Note. Abbreviations: NR, not reported. Studies used different terminology for similar outcomes therefore data from extravasation and infiltration outcomes were grouped under *infiltration*; displacement, traction, and dislodgement outcomes were grouped under *dislodgement*; and blockage, occlusion and obstruction outcomes were grouped under *occlusion*.
Statistical significance as reported in studies *$p \leq 0.05$, **$p \leq 0.01$, ***$p \leq 0.001$.

[a] At certain time points not PIVC failure.
[b] The results from the two intervention arms (B and C) were combined for comparison with control arm (A) in the closed and open systems and integrated and non-integrated.
[c] The results from one of two intervention arms (C) which was winged was used as a comparison with control arm (A) (non-winged).
[d] Catheter related infection as per pathology.
[e] Local site infection.
[f] Exact number per arm was not identified in González López's study - denominator calculated by using percentages provided in study table.
[g] Significant per-protocol.
[h] Significant at rate per 1000 device-days.

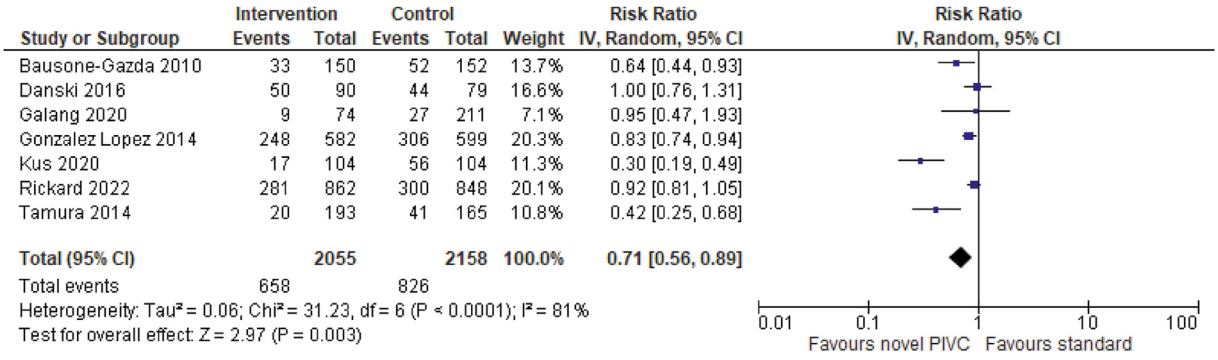

Figure 1 Random effects meta-analysis of PIVC failure in novel PIVC material and design versus standard PIVC.

was a confounder, a sensitivity analysis was conducted. After removing the Bausone study, the overall estimates of RR for phlebitis, dislodgement and infiltration remained statistically insignificant (Fig. S6).

Discussion

This systematic review and meta-analysis aimed to assess the effect of differing PIVC material and design on incidence of vascular access failure. Meta-analysis demonstrated reduced PIVC failure due when using PIVCs with novel material or design (vialon, integrated set, closed system, winged design) compared to standard care (teflon, non-integrated set, open system, non-winged design). Though the result was statistically significant, with the small number of studies, heterogeneities was substantial with high variability in the meta-analysis. However, we were able to determine a significant difference (with low heterogeneity) in subgroup meta-analysis using random effects between the closed and open systems. The risk of PIVC failure was 15% less when closed PIVC catheter systems used, compared to the open PIVC system. The rationale for this is uncertain — perhaps due to reduced manipulation on insertion or during use.

As only two of the seven studies reported the primary outcome of PIVC failure, composite measures for PIVC failure were used in this review to increase trial precision and efficacy [25]. Dwell time was reported inconsistently - four studies reported it at time of PIVC removal and the other three studies reported PIVC survival at certain time points (e.g., 72 h). Although we were unable to include infection outcomes in our meta-analysis, it remains the most serious PIVC complication due to breaching of the skin's protective barrier during PIVC insertion, creating an opportunity for microorganisms to enter the bloodstream [35]. While the incidence of PIVC related bloodstream infection (BSI) is lower than for a central venous catheter, the large volume of PIVCs (>2 billion purchased/year) means there is likely a high number of PIVC-BSIs each year [36,37]. Infection as an explicit outcome was only reported in two studies in this review and highlights the challenge clinicians, key decision makers and infection prevention and control teams face when designing strategies and selecting devices to use in healthcare settings.

Individual outcome indicators for PIVC complications of phlebitis, infiltration, dislodgement and occlusion were not seen to reflect statistically significant results for the different PIVC designs and materials. However, the majority of PIVC complications favoured the intervention group over standard of care. In particular, the impact of PIVC design and material on dislodgement favoured all the interventions in the subgroups (RR = 0.28—0.49). Though these results were not statistically significant, a risk of dislodgement of less than 50% in all four subgroups of PIVC material and design has clinical significance to clinicians and patients potentially reducing the need for unnecessary re-cannulation attempts.

There was a lack of consistency of defined outcomes in the studies, for example, phlebitis was defined differently in the studies or not at all and measured with diverse or non-identified assessment tools (which has been similarly reported in other literature [12,38]). Consequently, the outcomes evaluated were author defined and categorised in this review which introduces potential clinical heterogeneity but has the benefit of increasing generalisability [17]. Not all studies adjusted for confounders such as type of infusion, vascular health, or inserter competence, so the results should be interpreted with caution. However, the study populations in this review were mostly homogenous in age and were inpatients in similar ward settings.

Strengths/limitations

Strengths of this review are related to the overall systematic review method and analysis of contemporary trial research related the review question. However, there are limitations with the review. These are largely related to the relatively small number of studies, many with small participant number (n = 5 studies with <400 participants), and many with large variability in the estimated effect size as indicated by the wide confidence intervals of the risk ration of the included studies. Additionally, there was considerable clinical heterogeneity with interventions and outcome definitions as well as statistical heterogeneity demonstrated in proportion of variance in observed effect (I^2 value) [24]. The I^2 statistic can be imprecise and biased estimate of heterogeneity [39]. Therefore the 95% confidence interval of I^2 have been presented. Although I^2 values were high, the confidence intervals were wide suggesting uncertainty in heterogeneity estimates [24].

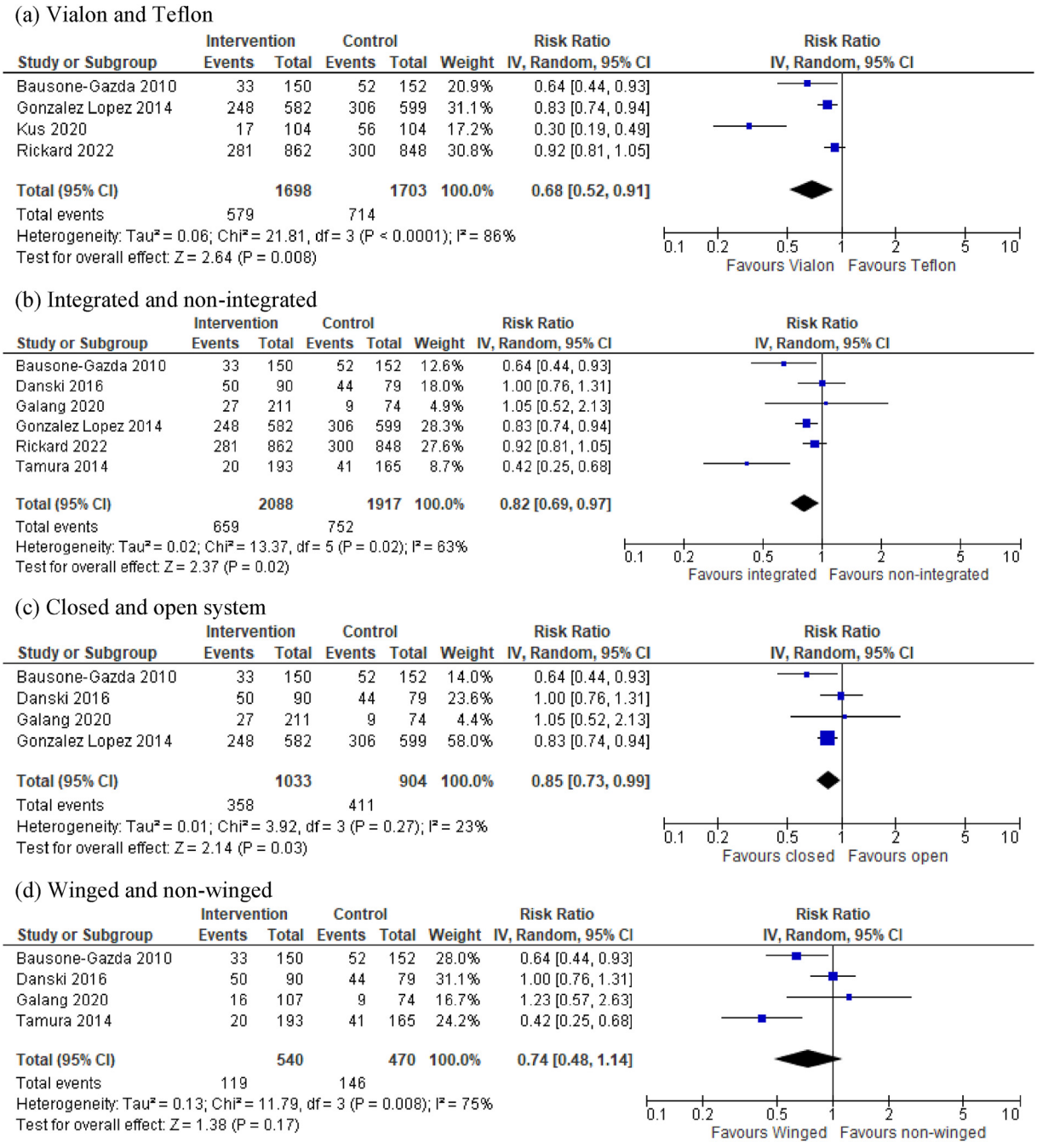

Figure 2 (a—d) Random effects meta-analysis of reported PIVC failure in intervention versus standard care subgroups (vialon and teflon, integrated and non-integrated, closed and open system and winged and non-winged PIVCs).

Recommendations

PIVC material and design should be considered in healthcare settings in their ability to impact PIVC survival and preserve vascular health of patients. Due to limited RCTs found on the impact of PIVC material and design in this review, more rigorous research conducted by large RCTs in multi centred settings is needed to guide clinicians in clinical practice, and inform evidence-based guidelines, local policies and procedures in the prevention of infection and other complications to improve patient experiences. Further research should report the outcomes found lacking in this review such as total PIVC failure, dwell time, infection (local and systemic), and include definitions of the core outcomes to decrease ambiguity [40]. Collaboration and consensus between experts in the field, and governing organisations are required to define these outcomes. Future meta-analyses with larger number of studies and sample sizes could not only provide further insights into types of PIVCs and risk of PIVC failure and complications, but also more accurate estimates of heterogeneity. Additionally, to improve the quality of future research and

reduce bias, future RCTs should be registered through the Cochrane Central Register of Controlled Trials, and biases such as blinding should be clearly stated.

Conclusion

This review identified that catheter material and design can impact PIVC failure. Meta-analysis of available data demonstrated that the closed system design is significantly associated with reduced PIVC failure. Conclusive recommendations are limited due to small number and quality of studies. Healthcare professionals require enhanced understanding of actual medical devices *and* practices that impact vessel health preservation. Further research in PIVC material and design is necessary, guided by the recommendations in this review, to improve clinical practice and future device selection pathways should reflect the resulting evidence.

Authorship statement

All authors have made substantial contributions to all of the following: (1) the conception and design of the study; acquisition of data; or analysis and interpretation of data; (2) drafting the article or revising it critically for important intellectual content; (3) final approval of the version to be submitted. Specifically: Conception of study and protocol development: all authors; study search and screening: RM, NG; data extraction RM, NG with NM, SK verifying/arbitrating; data analysis and reporting LM with RM, NG; initial manuscript draft RM, NG. All authors contributed to revisions of manuscript and approved final version.

Conflict of interest

SK reports monies received from her employer in the last 3 years from BD Medical and ITL Biomedical for educational consultancies unrelated to this study. NM reports that Griffith University and the University of Queensland have received, on her behalf, investigator-initiated research grants from 3M, BD, Eloquest and Cardinal Health; and a consultancy payment from BD. All other authors have nothing to declare.

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Ethics

Ethics approval not required as this is a discussion (or review) paper.

Data availability

Data is available from the corresponding author upon reasonable request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.idh.2023.05.005.

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