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REVIEW PAPER

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Drawing blood from peripheral intravenous cannula compared with venepuncture: A systematic review and meta-analysis

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Abstract

Aims: To synthesize the evidence evaluating if blood samples are similar when obtained from peripheral intravenous cannula compared with venepuncture.

Design: A systematic review and meta-analysis was undertaken.

Data sources: Searches were conducted in databases for English language studies between January 2000–December 2018.

Review methods: The search adhered to the Meta-analysis of Observational Studies in Epidemiology guidelines. The methodological quality of studies was assessed using Joanna Briggs critical appraisal instruments. The overall quality of the evidence was assessed using the GRADE.

Results: Sixteen studies were identified. Findings suggest haemolysis rates are higher in blood sampled from peripheral intravenous cannula. However, haemolysis rates may be lower if a peripheral intravenous cannula blood sampling protocol is followed. For equivalence of blood test results, even though some results were outside the laboratory, allowable error and were outside the Bland–Altman Level of Agreement, none of these values would have required clinical intervention. With regard to the contamination rates of blood cultures, the results were equivocal.

Conclusion: Further research is required to inform the evidence for best practice recommendations, including, if a protocol for drawing blood from a peripheral cannula is of benefit for specific patient populations and in other settings.

Impact: Venepuncture can provoke pain, anxiety and cause trauma to patients. Guidelines recommend blood samples from peripheral intravenous cannula be taken only on insertion. Anecdotal evidence suggests drawing blood from existing cannulas may be a common practice. Further research is required to resolve this issue.

KEYWORDS

acute care, adult nursing, diagnostic tests, haemolysis, peripheral venous catheterization, phlebotomy, systematic reviews and meta-analyses, venepuncture

1 | INTRODUCTION

Patients admitted to hospital are frequently subjected to multiple invasive tests including venepuncture and peripheral intravenous cannula (PIVC) insertion. Patients may require multiple blood tests to assist in diagnosis and management of medical conditions and the appropriate method of obtaining the blood sample can be a topic of debate. Venepuncture can provoke anxiety, be painful and uncomfortable, cause bruising, haematoma, infections, vasovagal reactions and in rare cases peripheral nerve damage (Buowari, 2013; Tsukuda et al., 2016). In the emergency department (ED) it is a common practice for staff to take the blood sample from a PIVC when a new line is placed. This reduces the need for an additional painful venepuncture. It is estimated that over a billion PIVCs worldwide are inserted each year (Alexandrou et al., 2018).

1.1 | Background

Current Australian (Clinical Excellence Commission, 2013; Government of Western Australia Department of Health, 2017; Queensland Government Department of Health, 2015) and UK national (Royal College of Nursing, 2016) guidelines state that blood samples may be drawn from a PIVC directly after insertion, but not at other times. Two guidelines (Gorski et al., 2016; Government of Western Australia Department of Health, 2017) also state consider obtaining a blood sample from a PIVC in an emergency, when the patient has limited vascular access, or is at increased risk of bleeding, or receiving thrombolytic therapy. Irrespective of current guidelines, anecdotal evidence suggests that withdrawing blood from PIVC may be a common practice. Patients may often need multiple blood tests to monitor their condition. Examples include the patient with gastrointestinal bleeding may need repeat haemoglobin; the patient with acute coronary syndrome may need repeat troponin; and the patient requiring glucose tolerance testing requires repeat blood glucose tests.

Advantages of withdrawing blood from a PIVC include convenience of access, decreased staff workload, low cost and less pain for the patient due to an additional venepuncture. Disadvantages may include risk of haemolysis, non-equivalence of the blood test results, risk of infection and risk to the patency of the cannula. Haemolysis, or red cell breakdown, can potentially lead to inaccurate blood test results and may require a second blood draw that leads to delay in treatment, increased staff workload, additional costs and unnecessary pain to patients due to the requirement of repeated blood tests. The American Society of Clinical Pathology benchmark for best practice define that the acceptable rate of sample rejection due to haemolysis is 2% or less (Lowe et al., 2008; Phelan, Reineks, Schold, Kovach, & Venkatesh, 2016). Estimates of haemolysis rates range from less than 1-36% (Phelan et al., 2016).

A recently published systematic review (McCaughey et al., 2017) explored differences in haemolysis rates; however, they did not conduct meta-analysis. We found no published systematic review that analysed the equivalence of blood test results. A systematic review (Snyder et al., 2012) examined effectiveness for reducing blood culture contamination rates and searched the literature up to 2011, so an update was timely. Although blood draws via venepuncture are considered a standard practice, a critical evaluation of the potential value of blood draws using the PIVC technique is required. Therefore, a systematic review including a meta-analysis was conducted to give an evidence-based answer to the research question.

2 | THE REVIEW

2.1 | Aims

The aim of this review was to synthesize the evidence evaluating if haemolysis rates, equivalence of blood results and contamination rates, between blood samples obtained from PIVC are comparable with venepuncture. As such, this review question is: Are haemolysis rates, blood test results and contamination rates comparable for blood samples obtained by PIVC and venepuncture for patients in acute health services?

2.2 | Design

2.2.1 | Types of participants

This review included studies involving adults aged 18 years and over who were admitted in an acute care hospital setting and required blood samples to be collected.

2.2.2 | Types of interventions

Types of interventions were studies that investigated the effect of drawing blood from a PIVC.

2.2.3 | Comparator

Only studies with venepuncture as the comparator were included.

2.2.4 | Outcome

This review included studies that investigated the following outcomes; haemolysis of blood samples, equivalence of blood samples and contamination of blood culture samples. It was decided a priori for equivalence of blood samples that only studies that conducted Bland–Altman plots and analysed mean differences in blood test results would be included (Bland & Altman, 1986). Other outcomes we considered but did not find any research on were risk of: catheter occlusion, phlebitis, dislodgement, device failure, catheter-related bloodstream infections, infiltration, blockage and cannula patency.

2.2.5 | Types of studies

This review considered published observational studies including randomized control trials, non-randomized control trials, quasi-experimental studies, before and after studies, prospective and retrospective cohort studies and analytical cross-sectional studies. This review also considered descriptive study designs for inclusion.

2.3 | Search methods

The search strategy adhered to the Meta-analysis of Observational Studies in Epidemiology study guidelines (Stroup et al., 2000) and was undertaken using the databases CINAHL, Cochrane Library, MEDLINE, Scopus, ISI Web of Science and Joanna Briggs. Two searches were conducted. The first search (January 2000–April 2017) was performed using a combination of search terms, including intravenous catheter OR intravenous cannula OR peripheral venous catheter OR peripheral venous cannula AND phlebotomy OR venepuncture OR direct venous puncture. The second search (January 2000–December 2018) was performed to update the literature and included the outcome measures in the search strategy. In addition, to the above terms we also included risk factors, infection, phlebitis, morbidity mortality, dwell time, device failure, device malfunction, occlusion, blockage, infiltration, extravasation and dislodgement with associated Boolean logic. The search strategy was adapted for the different databases and all terms were searched with Medical Subject Headings and as key (text) words (Appendix 1 & 2). In addition, the references of retrieved articles were checked and other articles that cited the retrieved articles were checked using citation alert with the ISI Web of Knowledge. Selection of papers for inclusion in the study was undertaken independently by two members of the research team.

We aimed to include all published research studies that were written in English. Studies published before 2000 were excluded. The rationale for this was such that the review reflected the contemporary practice in products with vascular access and phlebotomy. The invasive component of modern-day catheters are much more pliable and smooth compared with the polymeric nature of PIVCs before 2000 that may have had an impact on the results. Studies were excluded if they were conducted in paediatric (age <18 years) settings and if there was no direct comparison between blood samples obtained by PIVC and venepuncture.

2.4 | Search outcomes

The study selection process resulted in 855 studies being identified from the search strategy (Figure 1). Based on comparing the title and abstract of the citation against the inclusion criteria, 16 studies were identified as eligible (Barnard et al., 2016; Corbo, Fu, Silver, Atallah, & Bijur, 2007; Dietrich, 2014; Grant, 2003; Hambleton, Gomez, & Bernabeu Andreu, 2014; Himberger & Himberger, 2001; Kelly & Klim, 2013; Lowe et al., 2008; Munnix, Schellart, Gorissen, & Kleinveld,

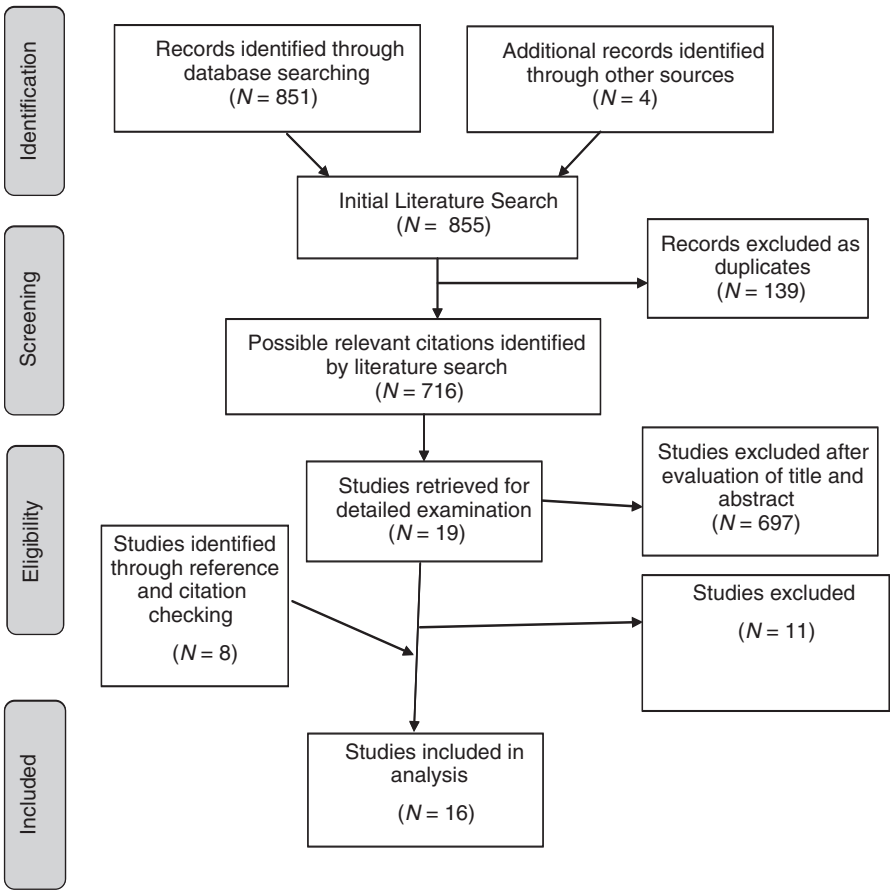


FIGURE 1 PRISMA flowchart of the study selection and inclusion process

TABLE 1 GRADE evidence profile – Peripheral Intravenous Cannula (PIVC) compared with venepuncture for drawing blood

Certainty assessment							Method of blood draw		Effect			
No of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Peripheral Intravenous Cannula (PIVC)	Venepuncture	Relative (95% CI)	Absolute (95% CI)	Certainty	Importance
Hemolysis of blood samples obtained by PIVC compared with venepuncture												
12	Observational studies	Very serious[a]	Not serious	Not serious	Not serious	Publication bias strongly suspected Very strong association All plausible residual confounding would reduce the demonstrated effect[b]	5673/59032 (9.6%)	70/6091 (1.1%)	OR 4.58 (3.61–5.80)	39 more per 1,000 (from 29 more to 52 more)	⨁⨁◯◯ low	Important
Equivalence of blood samples obtained by PIVC compared with venepuncture												
5	Observational studies	Very serious[c]	Not serious	Not serious	Not serious	Publication bias strongly suspected[d]	Two studies summarized the results as outside of the laboratory allowable error and outside Bland–Altman LOA, none of these values would have required clinical intervention. Two studies summarized the results as all parameters were within the laboratory's accepted error or considered equivalent except for venous blood gases. One study found blood samples for potassium, bicarbonate and glucose were not clinically equivalent.				⨁◯◯◯ very low	Critical

(Continues)

TABLE 1 (Continued)

Certainty assessment							Method of blood draw		Effect			
No of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Peripheral Intravenous Cannula (PIVC)	Venepuncture	Relative (95% CI)	Absolute (95% CI)	Certainty	Importance
Contamination of blood cultures obtained by PIVC compared with venepuncture												
2	Observational studies	Serious[e]	Very serious[f]	Not serious	Very serious[g]	Publication bias strongly suspected[h]	One study reported blood cultures could be taken accurately from a PIVC when compared with venepuncture; in contrast, the other study reported taking blood cultures from PIVC increases the risk of contamination.				⨁◯◯◯ very low	Important

Abbreviations: CI: Confidence interval; OR: Odds ratio.

GRADE Working Group grades of evidence.

High quality: Further research is very unlikely to change our confidence in the estimate of effect.

Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.

Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

Very low quality: We are very uncertain about the estimate.

[a]There was a high risk of bias: as the exposure (PIVC) could have been from a PIVC on insertion, newly inserted, or an existing PIVC; the outcome (haemolysis) was measured differently – either visually or automated; some studies did not control for confounding.

[b]The Funnel plot is not symmetrical, suggesting that publication bias may be of concern.

[c]There was a high risk of bias as: the exposure (PIVC) could have been from a newly inserted PIVC, or an existing PIVC; the outcome (equivalence) was measured differently among studies. Some defined clinical acceptable interval others used Bland–Altman 95% or 99% Level of Agreement (LOA). Some stated that even though the results were outside the clinical acceptable interval or the Bland–Altman LOA the values would not have required clinical intervention.

[d]We were only able to combine three studies and thus unable to do a Funnel Plot. The GRADE Handbook recommends, "It is extremely difficult to be confident that publication bias is absent and almost as difficult to place a threshold on when to rate down quality of evidence due to the strong suspicion of publication bias. For this reason GRADE suggests rating down quality of evidence for publication bias by a maximum of one level".

[e]There was a high risk of bias as: the exposure (PIVC) could be from a recently inserted PIVC or an existing PIVC.

[f]There was serious inconsistency in the results of the two studies.

[g]There was serious imprecision considering the small number of studies and wide confidence intervals.

[h]We conducted a narrative review and were unable to do a Funnel Plot. The GRADE Handbook recommends, "It is extremely difficult to be confident that publication bias is absent and almost as difficult to place a threshold on when to rate down quality of evidence due to the strong suspicion of publication bias. For this reason GRADE suggests rating down quality of evidence for publication bias by a maximum of one level".

TABLE 2 Results of quality appraisal (MAStARI)

JBI critical appraisal checklist for cross-sectional studies								
Author	**Criteria clearly defined**	**Subject and settings described**	**Exposure measured in valid and reliable way**	**Objective, standard criteria**	**Confounding factors identified**	**Strategies for confounding factors**	**Outcomes measured in valid and reliable way**	**Appropriate statistical analysis**
Barnard et al. (2016)	Unclear	Yes	Unclear	Yes	Yes	Yes	Yes	Yes
Corbo et al. (2007)	Yes	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes
Dietrich (2014)	Unclear	Unclear	Yes	Yes	Yes	No	Yes	Yes
Grant (2003)	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Lowe et al. (2008)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Munnix et al. (2010)	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Unclear
Ong et al. (2008)	Yes	Unclear	Unclear	Yes	Yes	Yes	Unclear	Yes
Ortells-Abuye et al. (2014)	Yes	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes
Phelan et al. (2018)	Unclear	Yes	Unclear	Yes	Yes	Yes	Yes	Yes
Seemann and Reinhardt (2000)	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Wollowitz et al. (2013)	Unclear	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Zlotowski et al. (2001)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Hambleton et al. (2014)	Yes	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes
Himberger and Himberger (2001)	Yes	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes
Self et al. (2012)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Kelly and Klim (2013)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

2010; Ong, Chan, & Lim, 2008; Ortells-Abuye, Busquets-Puigdevall, Díaz-Bergara, Paguina-Marcos, & Sánchez-Pérez, 2014; Phelan et al., 2018; Seemann & Reinhardt, 2000; Self et al., 2012; Wollowitz, Bijur, Esses, & Gallagher, 2013; Zlotowski, Kupas, & Wood, 2001).

2.5 | Quality appraisal

Studies selected for retrieval were assessed by two independent reviewers for methodological validity prior to inclusion in the review. We used the standardized Joanna Briggs Institute (JBI) critical appraisal instrument from the JBI Meta-Analysis of Statistics Assessment and Review Instrument (JBI MAStARI). Any disagreements that arose between the reviewers were resolved through discussion. Eleven studies were excluded (Appendix 3).

2.6 | Data abstraction

Data were extracted from the included studies by two reviewers to check accuracy. The data extracted included details about study year, study country, study aim, study setting, study design, interventions and comparators. Data were extracted separately for studies investigating haemolysis, accuracy of blood results and contamination of blood cultures. Data included sample type, sample size, methods, results and author recommendations.

2.7 | Synthesis

Meta-analysis was conducted for studies examining haemolysis. Forrest plots were produced to display the effect measures of each study that were expressed as prevalence, odds ratio (OR) with 95% confidence intervals (CIs). The OR is the ratio of the odds of haemolysis occurring in a blood sample obtained from a PIVC compared with the odds of haemolysis occurring in a blood sample obtained by venepuncture. A ratio of one implies the haemolysis of a blood sample is equally likely if obtained by both PIVC and venepuncture, a ratio of greater than one implies haemolysis is more likely in a blood sample obtained from PIVC and a ratio of less than one implies haemolysis is less likely if blood sample is obtained by PIVC.

Meta-analysis was also conducted for three studies (Corbo et al., 2007; Hambleton et al., 2014; Zlotowski et al., 2001) examining equivalence of blood results. We attempted to contact the authors for raw data and were unsuccessful for two studies (Himberger & Himberger, 2001; Ortells-Abuye et al., 2014). For one study (Hambleton et al., 2014) we used RevMan calculator (Review Manager (RevMan), 2014) to input the standard deviation and conduct statistical meta-analysis. Effect sizes were expressed as pooled mean differences and their 95% CI. Results were pooled using fixed effects models. Heterogeneity measures the variability among the combined studies and the chi-square test and the I^2 statistic were used to assess heterogeneity. The pooled result was considered heterogeneous if the I^2 statistic was >40% and the p value was <0.05 (Higgins & Green, 2011).

For some studies assessing equivalence of blood results and contamination of blood cultures, meta-analysis could not be performed, and the findings have, therefore, been presented in a narrative form. Tables are displayed to aid in data presentation wherever appropriate.

Publication bias may occur when studies with non-significant findings are not submitted by the investigator or are rejected by the editors of the journal (Gordis, 2009). When 10 or more studies were combined, publication bias was assessed using funnel plots and interpreted by visual inspection (Higgins & Green, 2011).

The overall quality of the evidence was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) assessment (Guyatt et al., 2008). A GRADE assessment includes assessment of risk of bias, inconsistency of results, indirectness of evidence, imprecision of results, the likelihood of publication bias, the magnitude of the effect and the effect of plausible residual confounding. The overall quality of the body of the evidence is then graded as high, moderate, low or very low. Two independent reviewers (LC and HD) performed the GRADE assessments, differences were discussed and consensus agreed (Table 1). A narrative summary of equivalence of blood results and contamination of blood cultures was conducted.

3 | RESULTS

3.1 | Characteristics of included studies

The 16 studies were critically appraised (Table 2) for methodological quality using the JBI critical appraisal tools. The overall methodological quality of the included studies was generally poor. Differences among the studies included if blood samples were obtained on insertion, from a newly inserted, or an existing PIVC. The outcome of haemolysis could have been measured either by visual inspection or by automated spectrometry. Confounding factors were not always identified and strategies to account for confounding factors were not always included.

The aims of the studies can be summarized as firstly to: examine blood sample haemolysis rates between blood samples drawn via venepuncture compared with PIVC (Barnard et al., 2016; Corbo et al., 2007; Dietrich, 2014; Grant, 2003; Lowe et al., 2008; Munnix et al., 2010; Ong et al., 2008; Ortells-Abuye et al., 2014; Phelan et al., 2018; Seemann & Reinhardt, 2000; Wollowitz et al., 2013; Zlotowski et al., 2001). Secondly, to examine equivalence of blood test results between blood samples drawn via PIVC compared with venepuncture (Corbo et al., 2007; Hambleton et al., 2014; Himberger & Himberger, 2001; Ortells-Abuye et al., 2014; Zlotowski et al., 2001). Thirdly, to examine blood culture contamination between blood samples drawn via venepuncture compared with PIVC (Kelly & Klim, 2013; Self et al., 2012).

Meta-analysis was conducted for the studies examining haemolysis. For the studies assessing equivalence, meta-analysis was conducted for three studies (Corbo et al., 2007; Hambleton et al., 2014; Zlotowski et al., 2001). Data could not be aggregated for two studies (Himberger & Himberger, 2001; Ortells-Abuye et al., 2014) of equivalence and the studies examining blood culture contamination.

TABLE 3 Summary of characteristics of included studies

Author Country	Setting	Data Collection	Sample type	Sample size	Methods
Barnard et al. (2016) UK	University teaching hospital Emergency department	Prospective	Convenience sample Collected over 3 months	Blood samples (*N* = 844) Blood sample: - Venepuncture (*N* = 257) - PIVC (*N* = 587)	
Corbo et al. (2007) USA	Urban tertiary hospital Level 1 Trauma Center Adult emergency department.	Prospective Observational Case–Control	Convenience sample Collected over 2 months *Inclusion* - Existing PIVC saline lock	Patients (*N* = 81) Usable patient samples (*N* = 73)	Concurrent samples *Existing PIVC* - Infusions halted 2min prior to tourniquet - Tourniquet proximal to intravenous line - Alcohol wipe - 5ml discard - Vacutainer used to aspirate blood sample *Venepuncture* - 21G butterfly needle - Vacutainer adaptor
Dietrich (2014) USA	188-bed level III Trauma Centre Emergency Department	Prospective Observational	Convenience sample Collected over 4-month period	Blood samples (*N* = 8,944) Blood sample: - On PIVC insertion (*N* = 3,803) - Venepuncture (*N* = 3,301) - Existing IV catheter (*N* = 1,840)	
Grant (2003) USA	Metropolitan teaching hospital Emergency Department	Prospective Observational	Convenience sample Collected over 19 days	Blood samples (*N* = 454) Blood sample: - On PIVC insertion (*N* = 255) - Venepuncture (*N* = 117) - Existing IV catheter (*N* = 82)	
Lowe et al. (2008) USA	450-bed Level II trauma centre Community teaching hospital Emergency Department	Prospective Observational	Non-consecutive sample Collected over 55 days	Blood samples (*N* = 853) Blood sample: - On PIVC insertion (*N* = 498) - Venepuncture (*N* = 355)	
Munnix et al. (2010) Netherlands	Hospital Emergency department & Outpatient clinic	Prospective Observational	Convenience sample Collected over 3 months	ED Patients (*N* = 100) Out Patients (*N* = 50) Blood Samples (*N* = 600) Blood sample drawn: - On PIVC insertion (*N* = 400) - Venepuncture (*N* = 200)	Consecutive patient specimens Four consecutive samples were collected for every patient
Ong et al. (2008) Singapore	Hospital Emergency Department	Prospective Observational	Convenience sample	Blood samples (*N* = 227) Blood sample drawn: - PIVC (*N* = 168) - Venepuncture (*N* = 59)	

(Continues)

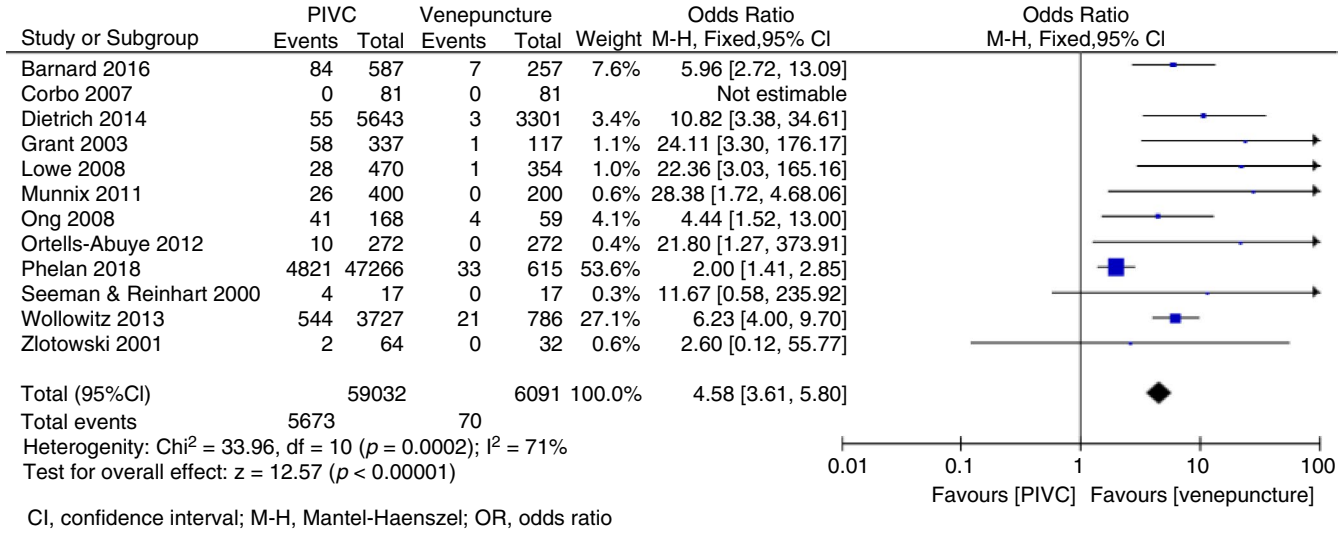
TABLE 3 (Continued)

Author Country	Setting	Data Collection	Sample type	Sample size	Methods
Ortells-Abuye et al. (2014) Spain	Reference 100-bed hospital Inpatient ward and Short Stay Unit	Cross-sectional study Simple crossover design	Collected over 8 months *Inclusion* - With a PIVC *Exclusion* - PIVC collection time > 20 s - Difficult venoclysis - Arterio-venous fistula - Language difficulties - Critical condition - Altered state of consciousness	Patients (*N* = 272)	Concurrent samples Randomized collection sequence *Existing PIVC* - IV fluid stopped for 15 s - Aspirated and discarded 4 ml of blood - Removed blood sample - Flushed PIVC with 4ml of saline *Venepuncture* - Opposite arm - 21-gauge needle - 10 ml syringe
Phelan et al. (2018) USA	Urban tertiary care hospital Emergency department	Retrospective Observational	All ED-obtained samples in which potassium analysis was completed Collected over 12 months	Blood samples (54,531) Blood sample: - PIVC (47,266) - Venepuncture (615)	
Seemann and Reinhardt (2000) USA	Medium-sized comprehensive healthcare facility Inpatient medical ward	Prospective Observational Case–Control	Convenience sample *Inclusion* - No coagulopathies or sepsis	Blood samples (*N* = 34) Blood sample: - Existing PIVC (*N* = 17) - Venepuncture (*N* = 17)	
Wollowitz et al. (2013) USA	Urban academic tertiary hospital Adult emergency department.	Prospective Observational Cross-Sectional	Convenience sample Collected over 40 days	Blood samples (*N* = 4,513) Blood sample: - Existing PIVC (*N* = 3,727 - Venepuncture using a butterfly needle (*N* = 786)	*Existing PIVC* - Closed IV catheter system-dual-port, attached to a BD vacutainer leurlock and 8.5ml BD vacutainer tube *Venepuncture* - Butterfly needle collection set (push button with 21- or 23-gauge butterfly needles)
Zlotowski et al. (2001) USA	Tertiary teaching hospital Emergency Department	Prospective Observational Case–Control	*Inclusion* - Healthy volunteers.	Sample size (*N* = 32) Blood samples (*N* = 96)	*Newly inserted PIVC* - PIVC inserted into upper extremity - 200ml bolus of NS administered over 10 min - 2 min wait time - Tourniquet applied - 18-gauge needle attached to a 20ml syringe aspirated 12ml of blood - A second aspirate of 12ml was similarly aspirated *Venepuncture* - 21-gauge butterfly needle - Vacutainer

(Continues)

TABLE 3 (Continued)

Author Country	Setting	Data Collection	Sample type	Sample size	Methods
Hambleton et al. (2014) Spain	University hospital Emergency department	Prospective Observational Case–Control	Consecutive enrolment Collected over 7 months *Exclusion* Patients with - anaemia - vascular disease - coagulopathy - receiving anticoagulation - immunocompromised - difficult venous access	Paired blood samples (*N* = 259)	Concurrent samples *Existing Double lumen PIVC* - Infusions halted 2min - Flushed both lumens with 1ml saline - 2 min later a tourniquet was applied - Alcohol wipe - 2 ml discarded - Vacutainer was used to aspirate blood sample *Venepuncture* - Opposite arm - 21-gauge butterfly needle
Himberger and Himberger (2001) USA	Military teaching hospital Regional Level 1 Trauma Centre Emergency department	Prospective Observational Case–Control	Convenience sample Collected over 10 months *Inclusion* - Adults - English Speaking - Receiving IV hydration - No Thrombophlebitis - Haemodynamically stable - SBP > 90mmHg - Capable of consent.	Patients (*N* = 64) Blood samples (*N* = 559)	Concurrent samples *Existing PIVC* - IV paused 30 s - Tourniquet applied - 30seconds pause - 5ml discarded - IV tube not disconnected from hub - 10ml syringe with an 18-gauge needle aspirated the blood sample - 10ml saline flush after *Venepuncture* - Opposite arm - 20-gauge needle
Kelly and Klim (2013) Australia	Community Teaching hospital Emergency department	Prospective Observational	Collected over 7-month period *Inclusion* - Required a blood culture - PIVC recently placed (<1hr) *Exclusion* - PIVC placed by paramedic	Sample size (*N* = 472)	Hospital policy on sterility, skin cleansing and blood culture bottle preparation was followed.
Self et al. (2012) USA	Teaching Hospital Adult emergency department.	Matched historical cohort	Collected over 12-month period	Sample size (*N* = 505) matched cultures	*Existing PIVC* - Skin antisepsis with 2% chlorhexidine/70% isopropyl alcohol prior to PIVC placement - Antisepsis of the catheter with 70% isopropyl - Drawing blood through the PIVC *Venepuncture* - Skin antisepsis with 2% chlorhexidine/70% ispropyl alcohol - Withdraw blood from the vein



CI, confidence interval; M-H, Mantel-Haenszel; OR, odds ratio

FIGURE 2 Forest plot of studies using OR in comparing haemolysis in blood samples taken via PIVC compared with venepuncture. CI, confidence interval; M-H, Mantel-Haenszel; OR, odds ratio [Colour figure can be viewed at wileyonlinelibrary.com]

Therefore, a narrative review is presented, as meta-analysis could not be performed.

Studies were conducted in the USA (Corbo et al., 2007; Dietrich, 2014; Grant, 2003; Himberger & Himberger, 2001; Lowe et al., 2008; Phelan et al., 2018; Seemann & Reinhardt, 2000; Self et al., 2012; Wollowitz et al., 2013),Europe(Barnard et al., 2016; Hambleton et al., 2014; Munnix et al., 2010; Ortells-Abuye et al., 2014), Australia (Kelly & Klim, 2013) and Singapore (Ong et al., 2008). Most of the studies were prospective (Barnard et al., 2016; Corbo et al., 2007; Dietrich, 2014; Grant, 2003; Hambleton et al., 2014; Himberger & Himberger, 2001; Kelly & Klim, 2013; Lowe et al., 2008; Munnix et al., 2010; Ong et al., 2008; Ortells-Abuye et al., 2014; Seemann & Reinhardt, 2000; Wollowitz et al., 2013; Zlotowski et al., 2001)and retrospective in nature (Phelan et al., 2018; Self et al., 2012). Many studies used the same group of patients, that is, one group of patients had blood samples from both PIVC and venepuncture (Corbo et al., 2007; Hambleton et al., 2014; Himberger & Himberger, 2001; Ortells-Abuye et al., 2014; Seemann & Reinhardt, 2000; Self et al., 2012; Zlotowski et al., 2001). Other studies used separate groups of patients for blood samples, that is, one group of patients blood was sampled from a PIVC and a separate group of patients had blood sampled by venepuncture (Barnard et al., 2016; Dietrich, 2014; Grant, 2003; Kelly & Klim, 2013; Lowe et al., 2008; Munnix et al., 2010; Ong et al., 2008; Phelan et al., 2018; Wollowitz et al., 2013).

Most studies were conducted in an emergency department (Barnard et al., 2016; Corbo et al., 2007; Dietrich, 2014; Grant, 2003; Hambleton et al., 2014; Himberger & Himberger, 2001; Kelly & Klim, 2013; Lowe et al., 2008; Munnix et al., 2010; Ong et al., 2008; Phelan et al., 2018; Self et al., 2012; Wollowitz et al., 2013; Zlotowski et al., 2001). One study was conducted in an inpatient ward and short stay unit (Ortells-Abuye et al., 2014) and one study in a medical ward (Seemann & Reinhardt, 2000).

Convenience sampling (Barnard et al., 2016; Corbo et al., 2007; Dietrich, 2014; Grant, 2003; Himberger & Himberger, 2001; Kelly & Klim, 2013; Lowe et al., 2008; Munnix et al., 2010; Ong et al., 2008; Phelan et al., 2018; Seemann & Reinhardt, 2000; Self et al., 2012; Wollowitz et al., 2013; Zlotowski et al., 2001) was common with three studies using consecutive sampling (Hambleton et al., 2014; Munnix et al., 2010; Ortells-Abuye et al., 2014). Sample sizes varied significantly with the number of patients being between 17 and 54,531 and data collection periods varying between 19 days and 12 months. A few studies excluded patients who were unstable or with multiple comorbidities (Hambleton et al., 2014; Himberger & Himberger, 2001; Ortells-Abuye et al., 2014; Seemann & Reinhardt, 2000) and one study only included healthy volunteers (Zlotowski et al., 2001).

Many studies clearly articulated protocols for collecting blood samples (Corbo et al., 2007; Hambleton et al., 2014; Himberger & Himberger, 2001; Kelly & Klim, 2013; Ortells-Abuye et al., 2014; Seemann & Reinhardt, 2000; Self et al., 2012; Wollowitz et al., 2013; Zlotowski et al., 2001) and others did not. Most studies sampled blood from existing PIVCs (Corbo et al., 2007; Hambleton et al., 2014; Himberger & Himberger, 2001; Ortells-Abuye et al., 2014; Seemann & Reinhardt, 2000; Self et al., 2012; Wollowitz et al., 2013); and a few studies sampled blood on PIVC insertion (Lowe et al., 2008; Munnix et al., 2010).Two studies (Dietrich, 2014; Grant, 2003) compared blood sampled from both existing PIVCs and on PIVC insertion; and two studies (Kelly & Klim, 2013; Zlotowski et al., 2001) stated blood was sampled from newly inserted PIVC (Table 3).The results have been presented according to studies investigating haemolysis, equivalence of blood results and contamination of blood cultures.

3.2 | Haemolysis

The rates of haemolysis from blood samples obtained between PIVC and venepuncture was reported in 10 studies (Figure 2). Meta-analysis found that the odds ratio of haemolysis were 4.58 (CI, 3.61–5.80) times more likely in blood samples obtained via PIVC compared with venepuncture. There was evidence of both clinical and statistical

TABLE 4 Haemolysis assessment methods, rejection rates and authors recommendations

Author	Haemolysis Assessment	Haemolysis sample rejection (haemolysis rate)	Authors recommendations
Barnard et al. (2016)	Haemolysis measured by spectrophotometry Haemolysis defined as ≥ 30μmol/l serum Hb	Total sample rejections: 92/844 (10.9%) - PIVC: 84/587 (14.3%) - Venepuncture: 7/257 (2.7%) (OR 5.63; 95% CI, 2.49 – 12.73) Sub-analyses *Side of patient* - Right: 57/450 (12.7%) - Left: 34/394 (8.6) (OR 0.68; 95% CI, 0.42 – 1.10) *Anatomical site* - Antecubital fossa: 50/637 (7.8%) - Distal to antecubital fossa: 41/207 (19.8% Significant (OR 2.25; 95% CI, 1.40 – 3.63) *Difficulty of sampling* - Very easy (compared to): 24/393 (6.1%) - Easy: 24/266 (9.0%) (OR 1.29; 95% CI, 0.69 – 2.35) - Average: 20/106 (18.9%) (OR 2.95; 95% CI, 1.51 – 5.77) - Difficult/ very difficult: 23/79 (29.1) (OR 4.36; 95% CI, 2.04 – 9.32) *Estimated tourniquet time* - <1min (compared to): 29/416 (7.0%) - 1–2min: 49/390 (12.6%) (OR 1.28; 95% CI, 0.76 – 2.16) - >2min: 13/38 (34.2%) (OR 2.15; 95% CI, 0.82 – 5.65)	• Where practicable all blood samples should be obtained via venepuncture rather than a PIVC • The overall economic impact of separating venepuncture and insertion of PIVC is complex and requires further evaluation.
Corbo et al. (2007)	Not reported.	No haemolysed samples No complications during aspiration of PIVC	• Aspirating blood via PIVC is an acceptable method of obtaining blood samples
Dietrich (2014)	Haemolysis measured by spectrophotometry Samples classified as: Usable – haemolysis < 200mg/dl Rejected – haemolysis > 200mg/dl Acceptable rate of sample rejection for haemolysis was defined as 2% as per benchmark best practice by the American Society of Clinical Pathology	Total sample rejections: 58/8,944 (0.65%) Sample rejection: - PIVC insertion: 41/3,803 (1.1%) - Venepuncture: 3/3,301 (0.1%) - Existing IV catheters: 14 /1,840 (0.8%)	• Measure haemolysis using standardized spectrophotometric measurement rather than colour charts • Levels of haemolysis required for rejection should be standardized • Actual costs of delayed laboratory results should be measured against the actual costs of performing additional venepunctures in all patients who already have IV access established but in whom no additional venepuncture is necessary.
Grant (2003)	Visual	Total sample rejections: 59/454 (13%) Sample rejection: - ED PIVC insertion: 50/255 (20%) - Venepuncture: 1/117 (<1%) - Existing IV catheters: 8/82 (10%) (20% vs. <1%, $p < 0.001$) Sub-analyses *ED PIVC insertion withdrawal method* Sample rejection: - Vacutainer: 44/195 (23%) - Syringe: 5/60 (9%) (22% vs. 9%, $p = 0.02$)	• Draw blood in ED PIVC insertion using a syringe instead of a vacutainer and then transfer blood to a tube via the needless connector

(Continues)

heterogeneity (chi-square = 33.96, $p = 0.0002$; $I^2 = 71\%$) and as such results must be interpreted with caution. Sensitivity analysis was conducted on five studies that followed a protocol for withdrawing blood from a PIVC. The findings were similar (OR 6.46; 95% CI, 4.21–9.91). There was no evidence of heterogeneity (chi-square = 1.22, $p = 0.75$; $I^2 = 0\%$).

Haemolysis was measured by either visual techniques (Grant, 2003; Lowe et al., 2008; Seemann & Reinhardt, 2000), automated techniques (Barnard et al., 2016; Corbo et al., 2007; Dietrich, 2014; Munnix et al., 2010; Phelan et al., 2018; Wollowitz et al., 2013), or the measurement technique was not reported (Ong et al., 2008; Ortells-Abuye et al., 2014; Zlotowski et al., 2001). Blood sample rejection

TABLE 4 (Continued)

Author	Haemolysis Assessment	Haemolysis sample rejection (haemolysis rate)	Authors recommendations
Lowe et al. (2008)	Haemolysis assessed visually Acceptable rate of sample rejection for haemolysis was defined as 2% as per benchmark best practice by the American Society of Clinical Pathology	Total sample rejections: 29/853 (3.4%) Sample rejection: - ED PIVC insertion: 28/470 (5.6%) - Venepuncture: 1/354 (<1%) (5.6% vs. <0.3%, p = 0.001) Sub-analyses Sample rejection by site *Venepuncture*; *PIVC* Antecubital 1/309 (<1%); 4/135 (2.9%) Forearm 0/18; 7/140 (5%) Hand 0/22; 12/99 (12%) Multi 0/1; 0/0 Wrist 0/2; 5/92 (5.4%) No significant differences	• Venepuncture should be the standard of care for drawing blood samples with the exception of high-acuity patients and patients who have difficult venous access.
Munnix et al. (2010)	Haemolysis measured by spectrophotometry	Total sample rejections 16/100 (16%) Sample rejection - PIVC: 16/100 (16%) - Venepuncture: 0/50 (0%) Sub-analysis *PIVC* - 1st tube: 16/100 (16%) - 2nd tube: 4/100 (4%) - 3rd tube: 4/100 (4%) - 4th tube: 2/100 (2%) *Difficult PIVC placement* - No: 6/77 (8%) - Yes: 10/23 (44%) *Size of needle* - 18 Gauge: 5/34 (15%) - 20 Gauge: 11/65 (17%) *Blood collection* - Needle with pre-attached holder: 10/86 (12%) - Direct draw adaptor: 6/12 (50%) *Site of blood draw* - Left antecubital: 4/31 (13%) - Right antecubital: 1/23 (4%) - Left forearm: 4/20 (20%) - Right forearm: 2/17 (12%) - Left hand: 2/3 (67%) - Right hand: 3/5 (60%) No statistical analyses reported	• The number of haemolysed specimens sent to the laboratory can be significantly reduced by elimination of the first tube of blood.

(Continues)

rates for haemolysis varied between collection methods: from venepuncture between 0-6.8%; from newly inserted PIVC between 0-20%; from existing PIVC between 0.8-24.4%; and from studies that followed a protocol between 0-5.6%. Two studies (Dietrich, 2014; Lowe et al., 2008) reported that the acceptable rate of sample rejection for haemolysis was defined by a 2% benchmark best practice set by the American Society of Clinical Pathology.

A few studies (Barnard et al., 2016; Grant, 2003; Lowe et al., 2008; Munnix et al., 2010; Ong et al., 2008; Phelan et al., 2018; Wollowitz et al., 2013) conducted sub-analyses; however, in one study (Munnix et al., 2010)no statistical analysis was performed making it difficult to ascertain the significance of findings. Two studies (Grant, 2003; Ong et al., 2008) found that the use of a vacutainer compared with syringe resulted in higher PIVC haemolysis rates and one study (Phelan et al., 2018) found no differences. Three studies (Barnard et al., 2016; Phelan et al., 2018; Wollowitz et al., 2013) found blood drawn from the antecubital fossa were less likely to be haemolysed when compared with blood drawn from other sites, in contrast to another study (Lowe et al., 2008) who found no differences related to blood draw site. Two studies (Phelan et al., 2018; Wollowitz et al., 2013) found that the use of larger gauge needles were less likely to have haemolysed samples compared with a smaller gauge needle, in contrast to another study by Ong et al., 2008 who found no differences related to needle gauge size. The same study (Wollowitz et al., 2013) also found that the blood samples were more likely to be haemolysed if the blood collection tube was less than half full. Two studies (Phelan et al., 2018; Wollowitz et al., 2013) found if the tourniquet time was greater than 1 min blood samples were more

TABLE 4 (Continued)

Author	Haemolysis Assessment	Haemolysis sample rejection (haemolysis rate)	Authors recommendations
Ong et al. (2008)	Haemolysis assessed using validated methods in a biochemistry laboratory.	Total sample rejections: 45/227 (19.8%) Sample rejection - PIVC: 41/168 (24.4%) - Venepuncture: 4/59 (6.8%) Univariable analysis: (OR 4.4; 95% CI, 1.5 – 13.0) *Univariable Sub analysis* - Syringe: 16 /146 (11%) - Vacutainer: 29/81 (35.8%) (OR 4.5; 95% CI, 2.3 – 9.0) *Size of needle* - ≤ 21G: 15/86 (17.4%) - > 21G: 30/141 (21.3%) Not significant *Operator* - Registrar: 2/18 (11.1%) - Medical officer: 22/137 (16.1%) - Consultant: 4/18 (22.2%) - Student/ nurse: 17/54 (31.5%) Not significant *Multivariable analysis* - Use of a vacutainer was associated with a significantly higher rates of haemolysis (adjusted OR, 6.0; 95% CI, 2.3 – 15.1)	• Drawing blood with a vacutainer had increased rates of haemolysis • If a syringe is used to draw blood, whether from IV cannula or venepuncture, a needless method should be used for sample transfer.
Ortells-Abuye et al. (2014)		Sample rejection: - Venepuncture 0/272 (0%) - PIVC 10/272 (3.7%)	• Blood samples obtained by venepuncture and PIVC can be used routinely for most routine laboratory tests
Phelan et al. (2018)	Haemolysis measured by spectrophotometry Haemolysis > 300 serum Hb = grossly haemolysed and sample rejected Haemolysis > 80 ≤ 300 serum Hb = haemolysed with comment	Total sample rejections: Combined (haemolysed with comment and gross haemolysis): 5,439/54,531 (10%) - PIVC: 4,821/47,266 (10.2%) - Venepuncture: 33/615 (5.4%) Significant Sub-analysis: PIVC *Site* - Antecubital: 2,117/28,786 (7.4%) - Peripheral: 2,622/17,960 (14.6%) - Significant *Syringe/ Vacutainer* - Syringe: 92/705 (13.0%) - Vacutainer: 1,825/16,590 (11.0%) Not significant *Size of needle* - 16 – 20 G: 3,882/44,571 (9.3%) - Other: 939/5,633 (16.7%) Significant *Tourniquet time* - >1 min: 532/3,832 (13.9%) - <1 min: 1,362/13,162 (10.3%) Significant	• Blood samples obtained by venepuncture and in the antecubital location are associated with reduced haemolysis • For blood samples obtained by PIVC shorter tourniquet times and larger gauge needle are associated with lower haemolysis
Seemann and Reinhardt (2000)	Haemolysis assessed visually	Total sample rejections: 4/34 (11.8%) Sample rejection: - Existing PIVC 4/17 (23.5%) - Venepuncture 0/17 (0%)	• PIVC is a valid method of producing viable blood samples

(Continues)

likely to be haemolysed with one study (Barnard et al., 2016) finding no differences. Two studies (Barnard et al., 2016; Wollowitz et al., 2013) found blood samples were more likely to be haemolysed if the venepuncture was difficult (Table 4).

3.3 | Equivalence of blood tests

Meta-analysis was conducted for three studies (Corbo et al., 2007; Hambleton et al., 2014; Zlotowski et al., 2001) that compared the

TABLE 4 (Continued)

Author	Haemolysis Assessment	Haemolysis sample rejection (haemolysis rate)	Authors recommendations
Wollowitz et al. (2013)	Haemolysis assessed by measurement of free serum haemoglobin levels	Total sample rejections 564/4513 (12.5%) Sample rejections: - PIVC 544/3727 (14.6%) - Venepuncture 21/786 (2.7%) Sub-analysis *Site of blood draw* - Antecubital fossa: 306 /3160 (9.7%) - Other: 260/1353 (19.2%) *Needle/catheter gauge* - 14–18 29/373 (7.8%) - 20 406/2922 (13.9%) - 21 6/322 (1.9%) - 23 15/464 (3.2%) *Fullness of collection tubes* - <half full 147/639 (23%) - ≥half full 418/3874 (10.8%) *Tourniquet time* - >1 min 214/1221 (17.5%) - ≤ 1 min 352/3,292 (10.7%) *Difficulty of venepuncture* - Difficult 224/954 (23.5%) - Not difficult 341/3559 (9.6%)	• The most effective strategy to reduce the rate of haemolysis in the ED is to use butterfly needles for phlebotomy rather than IV catheters.
Zlotowski et al. (2001)		Haemolysis from venepuncture 0/32 (0%) Haemolysis from PIVC 2/64 (3.1%)	• Supports use of blood samples obtained from PIVC

TABLE 5 Pooled mean and pooled mean difference between blood tests obtained by PIVC compared with venepuncture

Studies	Lab test	Number of blood tests	Pooled PIVC Mean	Pooled Venepuncture Mean	Pooled Mean Difference [95% CI]	Heterogeneity		
						Chi	*p*-value	I^2
Corbo et al. (2007); Hambleton et al. (2014); Zlotowski et al. (2001)	Sodium (mEq/L)	728	139.3	139.2	−0.10 [−0.13, 0.32]	0.4	0.8	0%
Corbo et al. (2007); Hambleton et al. (2014); Zlotowski et al. (2001)	Potassium (mEq/L)	728	3.9	3.9	−0.01 [−0.02, 0.01]	15.5	<0.001	87%
Corbo et al. (2007); Hambleton et al. (2014); Zlotowski et al. (2001)	Chloride (mEq/L)	728	105.2	104.9	0.32 [0.09, 0.5])	0.58	0.75	0%
Hambleton et al. (2014); Zlotowski et al. (2001)	Bicarbonate (mmol/L)	582	26.2	26.8	−0.6 [−0.8, −0.4]	0.59	0.44	0%
Corbo et al. (2007); Hambleton et al. (2014); Zlotowski et al. (2001)	Glucose (mg/dl)	728	116.6	116.4	0.6 [−0.4, 1.6]	0.88	0.64	0%
Hambleton et al. (2014); Zlotowski et al. (2001)	Albumin (g/dl)	582	3.6	3.6	−0.06 [−0.17, −0.05]	0.75	0.39	0%
Corbo et al. (2007); Hambleton et al. (2014)	Troponin (μg/L)	664	0.002	0.0017	0.00 [−0.00, 0.00]	0.79	0.37	0%
Hambleton et al. (2014); Zlotowski et al. (2001)	Hemoglobin (g/dl)	582	12.7	12.8	−0.1 [−0.13, −0.07]	0.07	0.8	0%
Corbo et al. (2007); Zlotowski et al. (2001)	Hematocrit (%)	210	38.5	38.7	−0.26 [−1.31. 0.79]	0.19	0.66	0%
Hambleton et al. (2014); Zlotowski et al. (2001)	Platelets (K/μl)	582	208.6	211.0	−2.4 [−3.48, −1.32]	0.0	0.98	0%
Hambleton et al. (2014); Zlotowski et al. (2001)	INR	582	1.1	1.2	−0.01 [−0.02, 0.00]	0.15	0.7	0%

TABLE 6 Equivalence of blood results

Author	Equivalence	Author recommendations					Author recommendations
Corbo et al. (2007)	*1. Difference between Lab tests and number exceeding CLIA standards and Bland-Altman LOA*						• Even though 43/584 (7.4%) could not be explained by allowable error for CLIA and 35/584 (6.0%) fell outside Bland-Altman LOA none of these values would have required clinical intervention • Samples for hemocrit, electrolytes, serum glucose, and cardiac enzymes can be taken from a PIVC saline lock device in stable patients in ED
	Lab Test	Venepuncture Mean (+*SD*)	PIVC Mean (+*SD*)	Mean difference	Number exceed National Recommended CLIA Range[a] *N* (%)	Number exceed Bland-Altman 95% LOA 1 *SD*; *N* (%)	
	Na+ *(mEq/L)*	140.1 (2.9)	140.4 (3.0)	−0.36	0 (0)	6 (8.2)	
	K+ *(mEq/L)*	4.1 (2.9)	4.1 (0.4)	−0.04	4 (5.5%)	2 (2.7%)	
	CO_2 *(mEq/L)*	25.5 (3.9)	25.5 (3.6)	−0.08	15 (20.5%)	4 (5.5%)	
	Cl- *(mEq/L)*	106.1 (3.5)	106.3 (3.5)	−0.23	0	5 (6.8%)	
	Glucose *(mg/dl)*	115 (57.0)	115.9 (58.1)	−0.60	7 (9.5%)	6 (8.2%)	
	CPK *(U/L)*	137.9 (223.9)	142.9 (224.6)	−5.019	4 (5.5%)	2 (2.7%)	
	Troponin I *(μg/L)*	0.004 (0.01)	0.006 (0.016)	−0.0016	12 (16.4%)	6 (8.2%)	
	HCT *(%)*	38.5 (3.9)	38.4 (4.0)	0.11	1 (1.3%)	4 (5.5%)	
	Total	43 (7.4%)	35 (6.0%)				
	2. Aspiration success rates						
	Catheter size	Number of success/ number of attempts	(95% CI)				
	18	6/6	100 (54.1–100)				
	20	63/69	91.3 (82–96.7)				
	22	4/6	66.7 (22.3–95.7)				
	Total	73/81	90.1 (81.5–95.6)				

(Continues)

TABLE 6 (Continued)

Author	Equivalence	Author recommendations					Author recommendations
Hambleton et al. (2014)	*1. Difference between Lab tests and number exceeding laboratory accepted systematic error and Bland-Altman LOA*						• Collecting bloods through PIVC is valid when analyzing for most commonly studied blood parameters in ED. • All parameters showed differences below the laboratory's accepted systematic error except for venous blood gases. • Remains valid regardless of the type of drug infusions administered. • The minimum discard of blood is twice the dead space volume of the device. • ED nurses should consider using PIVC as a first option for patients' blood draws.
	Lab Test	Venepuncture Mean (+*SD*)	PIVC Mean (+*SD*)	Mean diff	Differences below the laboratory accepted systematic error[b]	Number exceed Bland-Altman 95% LOA 2 *SD*; *N* (%)	
	Glucose	120.8	121.4	0.66	Yes	8 (3.5)	
	Urea	41.9	41.8	−0.05	Yes	16 (7.7)	
	Creatinine	1.09	1.07	−0.01	Yes	7 (3.0)	
	Na+	138.4	138.5	0.11	Yes	9 (3.9)	
	K+	3.9	3.9	−0.05	Yes	11 (5.1)	
	Cl-	104.9	105.2	0.33	Yes	9 (6.34)	
	Ca^{2+}	8.8	8.7	−0.08	Yes	14 (6.51)	
	Albumin	3.5	3.5	−0.05	Yes	15 (6.64)	
	Amylase	51.9	52.4	−0.54	Yes	4 (1.96)	
	Creatin Kinase	152.97	157.01	4.04	Yes	1 (0.5)	
	Bilirubin	0.7	0.6	−0.01	Yes	10 (5.6)	
	pH	7.4	7.4	0.01	Yes	4 (1.78)	
	pCO_2	43.8	42.01	−1.78	No	15 (6.52)	
	pO_2	38.6	45.6	7.01	No	20 (9.1)	
	HCO_3	26.6	25.97	−0.63	No	16 (6.9)	
	Troponin	1.1	1.1	0.04	Yes	1(2.0)	
	Osmolality	292.8	292.2	−0.58	Yes	2(2.6)	
	Leucocytes	9.1	8.99	−0.07	Yes	15 (6.2)	
	Red Blood Cells	4.3	4.3	−0.03	Yes	9 (3.8)	
	Hemoglobin	12.7	12.6	−0.11	Yes	17 (7.0)	
	Platlets	209.3	206.9	−2.34	Yes	16 (6.6)	
	aPTT	33.1	32.4	−0.63	Yes	20 (8.7)	
	INR	1.2	1.2	0.01	Yes	6 (2.6)	

(Continues)

TABLE 6 (Continued)

Author	Equivalence	Author recommendations					Author recommendations
Himberger and Himberger, (2001)	*1. Difference between Lab tests and number exceeding laboratory clinical accepted internval and Bland-Altman LOA*						• Bloods can be collected from venepuncture and PIVC interchangeably • Even though a few values exceeded the LOA these values would not result in clinical treatment • Strict adherence to procedure protocols is necessary • Each specimen should be monitored for haemolysis
	Lab Test	Venepuncture Mean (+*SD*)	PIVC Mean (+*SD*)	Mean difference	Number exceed National Recommended CLIA Range[a] *N* (%)	Number exceed Bland-Altman 95% LOA 1 *SD*; *N* (%)	
	WBC x 10^9/L	Not reported	Not reported	−0.02	0/46 (0%)	0 (0%)	
	RBC x 10^6/μl			0.09	0/46 (0%)	0 (0%)	
	Hct			−1.5	0/46 (0%)	2 (4.4%)	
	Hgb g/dl			0.1	2/46 (4.4%)	3 (6.5%)	
	Plt x10^9			−0.2	1/46 (2.2%) 3 (6.5%)		
	Sodium mEq/L			0.4	1/47(2.1%)	3 (6.4%)	
	Potassium mEq/L			0.05	2/47 (4.3%)	3 (6.4%)	
	Chloride mEq/L			0.3	1/47 (2.1%)	3 (6.4%)	
	$C0_2$ mEq/L			0.15	2/47 (4.3%)	2 (4.3%)	
	Glucose mg/dl			−2.44	3/47 (6.4%)	2 (4.3%)	
	Creatinine mg/dl			0.17	1/47 (2.1%)	2 (4.3%)	
	SUN mg/dl			0.1	1/47 (2.1%)	1 (2.1%)	
	2. Overall success rate 58/64 (90.7%) of aspirating blood from a PIVC						
	3. There were no reported complications with IV site with any study participants indicating this is a safe and effective method for obtaining blood specimens						

(Continues)

TABLE 6 (Continued)

Author	Equivalence	Author recommendations					Author recommendations
Ortells-Abuye et al. (2014)	1. Difference between Lab tests and number exceeding laboratory clinical accepted internval and Bland-Altman LOA						• Venepuncture and PIVC can be considered equivalent for most routine laboratory tests but not pCO2 and pO2 • Non-equivalence of pCO2 and pO2 may be due to handling and transfer of blood sample to blood gas syringe • If patients have existing PIVC, using that for blood draws is preferable • PIVC could be used for blood draws in patients who are bleeding or have infectious disease and require multiple requests for haemograms
	Lab Test	Venepuncture Mean (+*SD*)	PIVC Mean (+*SD*)	Mean difference	Number exceed National Recommended CLIA Range[c] *N* (%)	Number exceed Bland-Altman 95% LOA 1 *SD*; *N* (%)	
	Amylase U/L	Not reported	Not reported	Not reported	1/265 (0.4%)	1/265 (0.4%)	
	Calcium mg/dl				2/266 (0.8%)	7/266 (2.6)%	
	Total cholesterol				12/269 (4.5%)	6/269 (2.2%)	
	Creatinine mg/dl				4/271 (1.5%)	4/271 (1.5%)	
	Creatinine kinase U/L				13/262 (5.0%)	9/262 (3.4%)	
	Basal glucose mg/dl				17/271 (6.3%)	9/272 (3.3%)	
	Aspartate aminotransferase (SGOT) U/L				7/269 (2.6%)	11/269 (4.1%)	
	Potassium mEq/L				19/269 (7.1%)	13/269 (4.8%)	
	Sodium mEq/L				4/271 (1.5%)	12/271 (4.4%)	
	Urea mg/dl				9/269 (3.3%)	7/269 (2.6%)	
	Red blood cells 10^6/μl				3/268 (1.1%)	12/268 (4.5%)	
	Haemoglobin g/dl				9/268 (3.4%)	8/268 (3.0%)	
	Leucocytes 10^3/μl				4/268 (1.5%)	5/268 (1.9%)	
	Platelets 103/μl				3/267 (1.1%)	7/267 (2.6%)	
	Prothrombin ratio (%)				22/269 (8.2%)	5/269 (1.9%)	
	Venous CO_2 potential pH				2/260 (0.8%)	11/260 (4.2%)	
	Venous CO_2 partial pressure pCO_2 mm Hg				55/260 (21.2%)	10/260 (3.8%)	
	Venous O_2 partial pressure pO_2 mm Hg				190/260 (73.1%)	10/260 (3.8%)	

(Continues)

TABLE 6 (Continued)

Author	Equivalence	Author recommendations					Author recommendations
Zlotowski et al. (2001)	1. Mean difference between Lab tests, Bland-Altman 99% LOA, Clinical significant value and equivalence						• Blood samples for CBC; blood urea; nitrogen; creatinine; liver function and PT/INR were determined clinically equivalent when from PIVC. • Blood samples for potassium, bicarbonate and glucose were not determined clinically equivalent when from PIVC.
	Lab Test	Venepuncture Mean (+*SD*)	PIVC Mean (+*SD*)	Mean difference	Number exceed National Recommended CLIA Range[d] *N* (%)	Number exceed Bland-Altman 95% LOA 1 *SD*; *N* (%)	
	Na mmol/L	143.6 (1.6)	143.5 (1.8)	0.09	−2.55–2.74	5.0	
	K mmol/L	3.8 (0.22)	3.6 (0.2)	0.17	−0.25–0.60	0.3	
	Cl mmol/L	101.9 (2.1)	102.6 (2.2)	−0.69	−3.50–2.12	8.0	
	HCO^3 mmol/L	28.7 (2.0)	27.7 (2.0)	0.97	−3.14–5.08	3.0	
	Glucose	83.1 (10.0)	81.4 (10.4)	1.72	−16.0–19.43	5.0	
	BUN mg/dl	13.7 (3.3)	13.1 (3.6)	0.53	−2.24–3.31	5.0	
	Creatinine mg/dl	0.9 (0.1)	0.9 (0.2)	0.01	−0.13–0.16	0.3	
	Albumin g/dl	4.4 (0.2)	4.3 (0.3)	0.10	−0.18–0.38	0.4	
	Total Bili mg/dl	0.4 (0.2)	0.4 (0.2)	−0.01	−0.15–0.14	0.4	
	Direct Bili mg/dl	0.1 (0.03)	0.12 (0.06)	−0.01	−0.11–0.09	0.2	
	ALP U/L	63.8 (17.8)	62.2 (17.7)	1.53	−5.14–8.20	20.0	
	ALT U/L	21.0 (13.8)	21.2 (13.4)	−0.25	−6.32–5.82	15.0	
	AST U/L	27.9 (13.0)	27.1 (13.3)	0.78	−9.74–11.31	15.0	
	WBC K/μl	5.5 (1.4)	5.6 (1.4)	−0.01	−0.70–0.68	1.0	
	Hb g/dl	13.7 (1.5)	13.5 (1.6)	0.24	−0.47–0.94	1.0	
	Hct (%)	39.4 (3.7)	38.8 (3.8)	0.67	−1.33–2.66	4.0	
	Plt K/μl	224.9 (47.2)	222.2 (46.7)	2.69	−12.98–18.35	30.0	
	PT (s)	13.1 (1.5)	13.2 (0.5)	−0.07	−0.67–0.54	1.5	
	INR	1.0 (0.07)	1.0 (0.07)	−0.01	−0.10–0.08	0.2	
	2. Overall success rate 32/32 (100.0%) of aspirating blood from a PIVC						

[a]CLIA, 'Clinical laboratory Improvement Amendments' are a set of regulations that are set out by the Centre for Disease Control and Food and Drug Administration in the United States, and are used to provide industry standards for laboratory testing quality.
[b]Laboratory Accepted Systematic Error, Used the International Organization for Standardization. ISO 15189:2007: Medical laboratories—particular requirements for quality and competence. Available from the ISO webpage https://www.iso.org/standard/42641.html.
[c]Clinically Accepted Interval was defined by the study investigators to be the minimal clinically significant difference between venepuncture and PIVC.
[d]Clinically Significant Value was based on the median values of the expert opinion of 5 emergency staff physicians.

equivalence of blood tests between PIVC and venepuncture (Table 5). There were no significant mean differences in most blood tests with the exception of platelets and bicarbonate (mean values were lower in the PIVC group compared with the venepuncture group) and chloride (mean value was higher in the PIVC group compared with the venepuncture group). Statistical heterogeneity was not present in any pooled analyses except potassium, where the I^2 value was 87%. This result showed the substantial heterogeneity which must be interpreted with care as there is considerable variation in the combined or pooled results and it may be misleading to report a combined summary measure. Two studies (Himberger & Himberger, 2001; Ortells-Abuye et al., 2014) were unable to be combined for meta-analysis and the following data are a narrative synthesis of the findings of all five studies reporting blood test equivalence.

It is worth noting that, studies defined the clinically accepted interval differently; two studies (Corbo et al., 2007; Himberger & Himberger, 2001) used the Clinical Laboratory Improvement Amendments (CLIA), that are a set of regulations set out by the Centre for Disease Control and the Food and Drug Administration, that offer industry standards for laboratory testing quality. One study (Hambleton et al., 2014) used the Laboratory Accepted Systematic Error; in another study (Ortells-Abuye et al., 2014), the investigators defined the clinically acceptable interval; and in the last study (Zlotowski et al., 2001); an expert panel of five emergency physicians defined the clinically acceptable interval. Similarly, four studies (Corbo et al., 2007; Hambleton et al., 2014; Himberger & Himberger, 2001; Ortells-Abuye et al., 2014) used Bland–Altman 95% level of agreement (LOA) and one study (Zlotowski et al., 2001) used Bland–Altman 99% LOA.

Two studies (Corbo et al., 2007; Himberger & Himberger, 2001) summarized the results as not requiring clinical intervention, even though some values were outside the laboratory allowable error and were outside Bland–Altman LOA. One study (Hambleton et al., 2014) summarized the results as all parameters were within the laboratory's accepted error except for venous blood gases. Similarly, another study (Ortells-Abuye et al., 2014) also summarized blood results, which could be considered equivalent with the exception of venous blood gases. In contrast, one study (Zlotowski et al., 2001) found blood samples for potassium, bicarbonate and glucose were not clinically equivalent.

In addition, three studies (Corbo et al., 2007; Himberger & Himberger, 2001; Zlotowski et al., 2001) reported that the aspiration of PIVC success rates were between 90% and 100%; with one study (Corbo et al., 2007) further analysing aspiration success for 18-, 20- and 22-gauge needles (100%, 91.3%, 66.7% respectively). Another study (Hambleton et al., 2014) reported blood samples from PIVCs with and without infusions and venepuncture were similar; and one study (Himberger & Himberger, 2001) reported no complications with the PIVC with any of the study participants and concluded withdrawing blood from a PIVC was safe and effective method of obtaining blood samples (Table 6).

3.4 | Contamination of blood cultures

Two studies (Kelly & Klim, 2013; Self et al., 2012) examined the rate of contamination of blood cultures if the blood sample was taken from a PIVC compared with venepuncture (Table 7).One study (Kelly & Klim, 2013) reported blood cultures could be taken accurately from a PIVC within 1 hr of PIVC insertion when compared with venepuncture. In contrast, the other study (Self et al., 2012) reported

TABLE 7 Contamination of blood cultures

Author	Results: Blood cultures	Author recommendations
Kelly and Klim (2013)	1. Number of positive cultures: *N* = 65/472, (13.8%) 2. Number of true positive cultures: *N* = 49/65, (75.4%) 3. Number of false positive cultures: *N* = 16/65, (24.6%)False positive via venepuncture: *N* = 8/224 (3.6%) False positive via PIVC: *N* = 8/248 (3.2%) 4. Odds ratio for contaminated cultures in PIVC: (OR, 0.9; 95%CI, 0.33–2.44)	• Blood cultures can be accurately taken from a PIVC within 1hr of insertion in an ED when infection control procedures are followed.
Self et al. (2012)	1. Overall 2. PIVC contaminated: 33/505 (6.5%) 3. Venepuncture contaminated: 18/505 (3.6%) 4. Relative risk of contamination PIVC compared with venepuncture (RR 1.83; 95% CI, 1.08–3.11)Use of PIVC compared with venepuncture resulted in 2.97 (95%CI, 0.29–7.51) additional contaminated cultures per 100 cultures collected	• This study suggests that collecting blood cultures from PIVCs increases the risk of contamination compared with venepuncture

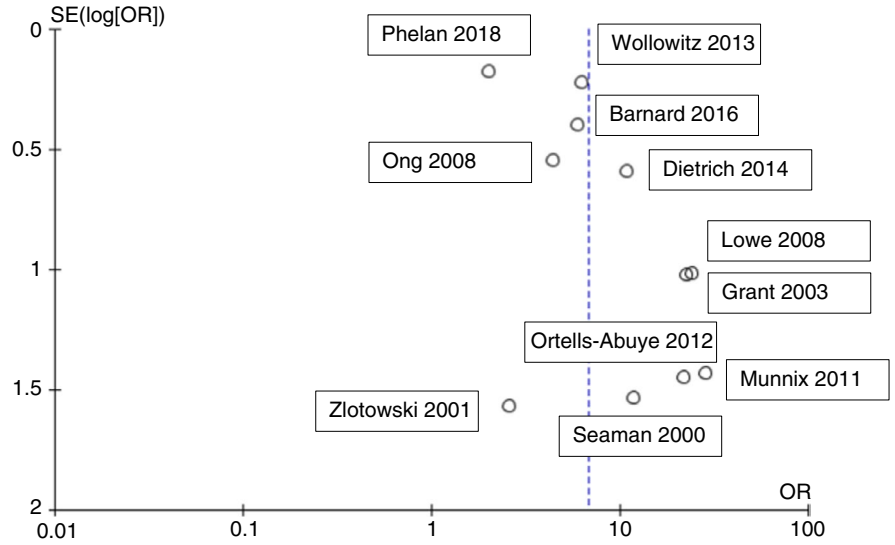


FIGURE 3 Funnel plot for the pooled OR of haemolysis. Abbreviations: SE(log[OR]) : Standard Error (logarithm[Odds Ratio]) [Colour figure can be viewed at wileyonlinelibrary.com]

taking blood cultures from PIVC increases the risk of contamination and false positive results compared with venepuncture.

3.5 | Publication bias

A funnel plot was used to assess publication bias for the studies on haemolysis. The plot is not symmetrical, suggesting that publication bias may be of concern. Figure 3 displays the funnel plot for the pooled OR of haemolysis.

4 | DISCUSSION

This review synthesized the studies on the effect of obtaining blood samples from a PIVC compared with venepuncture. Sixteen studies met the inclusion criteria, with 12 studies examining haemolysis rates, five studies examining equivalence of blood test results and two studies examining contamination rates of blood cultures. We did not find any study that investigated risk of blood stream infection and risk to the patency of the cannula after withdrawing blood samples from the PIVC. Major findings of this review suggest that haemolysis rates are higher in blood sampled from a PIVC compared with venepuncture. With regard to equivalence of blood test results, even though some results were outside the laboratory allowable error and were outside the Bland–Altman LOA, none of these values would have required clinical intervention. Some studies did not consider venous blood gases were equivalent and a single study found blood samples for potassium, bicarbonate and glucose were not clinically equivalent. With regard to contamination rates of blood cultures, the results were equivocal.

In this systematic review, we highlighted variations in drawing blood from a PIVC (on insertion, newly inserted, or an existing PIVC), in how the outcome of haemolysis was measured (visually or automated) and some studies did not control for confounding (e.g. vacutainer vs. syringe, needle gauge, site of blood drawn etc.). The visual method of detecting haemolysis is subjective and depends on the individual's visual acuity and colour perception (Dietrich, 2014). The outcome of equivalence was measured differently among the studies (e.g. clinical acceptable intervals and Bland–Altman plots). These variations certainly impede the strength of recommendations that can be drawn across studies. Nonetheless, there was sufficient homogeneity to allow meta-analysis of the studies of haemolysis.

Meta-analysis found the odds of haemolysis were 4.58 times more likely in blood samples obtained via PIVC compared with venepuncture. This finding is similar to other systematic reviews (Heyer et al., 2012; McCaughey et al., 2017). In our study, haemolysis rates for blood obtained via venepuncture were low and less than 2.7% in nine of 10 studies. Interestingly, the haemolysis rates for blood obtained via PIVC varied greatly also between 0% and 24.4%, with five studies (Corbo et al., 2007; Dietrich, 2014; Lowe et al., 2008; Ortells-Abuye et al., 2014; Zlotowski et al., 2001)that followed a protocol for withdrawing blood reporting haemolysis rates between 0-5.6%. Even though our sensitivity analysis conducted on the five studies that followed a protocol were similar (OR 6.46) we contend haemolysis rates less than 5% are approaching the American Society of Clinical Pathology benchmark of 2%. Accepting haemolysis rates of less than 5% in patients known to be a difficult venepuncture or who require multiple blood draws may be considered a pragmatic option. In addition, one study (Grant, 2003) that reported a high haemolysis rate (20%) implemented a clinical practice change and encouraged phlebotomists to sample blood with a syringe instead of a vacutainer and then transfer the blood to a tube via a needleless connector. Audits following this practice change showed haemolysis rates had decreased between 4-5%. Other variables that may be important regarding haemolysis rates include site of the blood drawn, the needle gauge, the

fullness of the collection tube, tourniquet use and if the venepuncture was considered difficult.

Most of the studies considered blood samples from venepuncture and PIVC were equivalent. Irrespective of the laboratory clinically accepted error or Bland–Altman analyses it seems logical to evaluate equivalence with whether the difference in tests would require clinical intervention. Non-equivalence of venous blood gases has been suggested due to handling error. In that, contact with air may cause changes in blood results. The blood sample needs to be transferred from a syringe to a blood gas syringe, the blood gas syringe needs to be filled with the correct amount of blood and excess air needs to be removed. The study (Zlotowski et al., 2001) that reported non-equivalence for potassium, bicarbonate and glucose suggested this may be related to haemodilution, as they compared the results after administering a normal saline solution bolus.

We only found two studies that evaluated contamination of blood cultures between venepuncture and PIVC. One study supported obtaining blood cultures from PIVC and the other study did not. Considering another meta-analysis (Snyder et al., 2012) evaluating venepuncture with intravenous catheters recommended against obtaining blood from an intravenous catheter due to increased contamination rates, we also support this recommendation. This meta-analysis (Snyder et al., 2012) was different to ours in that it included intravenous catheters comprising of central lines, arterial lines and portacatheters and included studies with paediatric patients.

4.1 | Limitations

This review has some limitations. Some studies examining equivalence of blood test results were excluded as their data analyses reported paired *t* tests and correlation coefficients. It was determined a priori the most appropriate analyses were the Bland–Altman method (Bland & Altman, 1986). This review was limited to English language studies, a limitation that may also introduce bias. Even though we followed the Meta-analysis of Observational Studies in Epidemiology guidelines (Stroup et al., 2000) there remains some subjectivity in consensus agreement for rating study quality for inclusion and grading the overall strength of the evidence.

The range of settings in the reviewed studies has implications for clinical and statistical heterogeneity with systematic reviews and meta-analyses but enhances generalizability. The results of this review have generalizability limited to adult patients in acute care and emergency settings. Limitations outside the control of the review authors included: all the studies were from single institutions; some studies had small sample sizes; many studies did not include unstable patients; and most of the laboratory results analysed fell inside the normal range. In addition, a wide variety of practices were observed for drawing blood from a PIVC and not all studies controlled for confounding variables.

4.2 | Recommendations for practice

The results of this review can help guide clinical practice in several ways. This systematic review showed that five studies with haemolysis rates less than 5% used a protocol to withdraw blood from a PIVC and one study had lower rates of haemolysis after implementing a protocol to withdraw blood from a PIVC. Some of the suggestions flowing on from this review until supported by further research suggest that a PIVC protocol should include: strict aseptic technique; halt infusion of solution for at least 2 min prior to blood draw; use a 20-gauge or larger catheter; and the quantity of blood to be discarded should be double the dead space. Other suggestions included using a needleless connector to draw blood from the PIVC, thus reducing the opportunity of a potential needle stick injury, use a syringe to aspirate the blood not a vacutainer and avoid excessive aspiration force and do not under-fill the blood tubes.

Hospitals should also be encouraged to audit haemolysis rates regularly in their departments, not only to increase staff awareness, but also to potentially implement clinical practice change to decrease haemolysis rates if required.

4.3 | Recommendations for research

Large randomized controlled multisite trials are required to definitively compare effectiveness of PIVC blood draws compared with venepuncture. A cluster design is recommended to investigate the effect of a blood draw protocol. The cluster design will manage the risk of contamination of the blood draw protocol between the intervention and control group. All studies need to clearly articulate if the blood was sampled from the PIVC on-insertion, newly inserted or from an existing PIVC. The studies need to evaluate if drawing blood from a PIVC influences premature cannula failure, cause phlebitis, leading to blood-stream infections and economic analyses should be conducted.

More studies are required that analyse abnormal laboratory values, that is, values outside the normal range. Analysis of equivalence of blood test results should be reported using clinical acceptable laboratory error, Bland–Altman plots and more importantly would the result of changed clinical treatment.

Further research is required to investigate if drawing blood from a PIVC is of benefit for specific patient populations and in other settings besides the emergency department. Some examples include patients who are known to be a difficult venepuncture; who have limited venous access; require multiple blood draws; who are obese, dehydrated or oedematous; and patients on anticoagulation therapy who are at increased risk of bleeding. Moreover, there has been a recent single study (Mulloy, Lee, Gregas, Hoffman, & Ashley, 2018) into a device that attaches to the PIVC and threads a sterile catheter through the PIVC into the vein allowing needle-free blood draws. This study should be replicated in different patient populations and an economic analysis conducted.

5 | CONCLUSION

Hospitalized patients often require multiple blood tests to assist in diagnosis and management of their conditions. Findings from this

review suggest blood samples for PIVC compared with venepuncture have higher haemolysis rates; however, some individual studies demonstrated that if a protocol was followed, these rates may be lower. Blood test results may be considered equivalent as differences in results would not affect clinical treatment and blood cultures should not be taken from PIVC. Furthermore, drawing blood from PIVCs may be the best available option in some patient groups, however, further research is required to inform the evidence for best practice recommendations.

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CONFLICT OF INTEREST

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AUTHOR CONTRIBUTIONS

LC, AJ, HD, LS, SK, EJ: Made substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data; LC, AJ, HD, LS, SK, EJ: Involved in drafting the manuscript or revising it critically for important intellectual content; LC, AJ, HD, LS, SK, EJ: Given final approval of the version to be published. Each author should have participated sufficiently in the work to take public responsibility for appropriate portions of the content; LC, AJ, HD, LS, SK, EJ: Agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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APPENDIX 1

ELECTRONIC DATABASE FIRST SEARCH STRATEGY (JANUARY 2000–APRIL 2017)

MEDLINE search strategy

(((MH "phlebotomy")) OR ("direct venous puncture") OR ("venepuncture") AND ((MH "cannula")) OR ((MH "Catheter")) OR ("intravenous cannula*") OR ("intravenous catheter*") OR ("peripheral venous catheter*") OR ("peripheral venous cannula*") OR ("peripheral catheter*") OR ("peripheral cannula*"))

CINAHL search strategy

(((MH "phlebotomy")) OR ("direct venous puncture") OR ("venepuncture") AND ((MH "cannula")) OR ((MH "Catheter")) OR ("intravenous cannula*") OR ("intravenous catheter*") OR ("peripheral venous catheter*") OR ("peripheral venous cannula*") OR ("peripheral catheter*") OR ("peripheral cannula*"))

Cochrane Library

(((MH "Phlebotomy")) OR ("venipuncture*") AND ((MH "Catheters")) OR (Cannula) or ((MH "Catheterization")) or (Peripheral Catheterization*))

Scopus

Keywords

((Phlebotomy)) OR (venepuncture)) ((Catheter*) OR (Intravenous Catheter))

ISI Web of Science

TS=(Phlebotom* OR Venepuncture* OR Direct Venous Puncture) AND TS=(Catheter* OR "Intravenous Catheter*" OR Catheteriz*)

Joanna Briggs (OVID)

(sh(Blood Specimen Collection) OR (Phlebotomy) OR (Venipuncture)) AND (sh(Catheter*) OR (Cannula))

APPENDIX 2

ELECTRONIC DATABASE SECOND SEARCH STRATEGY (1 JANUARY 2000–31 DECEMBER 2018)

MEDLINE search strategy

(((MH "phlebotomy")) OR ("direct venous puncture") OR ("venepuncture") AND ((MH "cannula")) OR ((MH "Catheter")) OR ("intravenous cannula*") OR ("intravenous catheter*") OR ("peripheral venous catheter*") OR ("peripheral venous cannula*") OR ("peripheral catheter*") OR ("peripheral cannula*")) AND "occlusion" OR (MH "phlebitis") OR "dislodge*" OR "failure" OR "device failure" OR "infection*" OR (MH "Catheter-Related Infections") OR "Infiltration" OR "extravasation" OR "blockage" OR "leakage" OR "he#molysis" OR "accuracy" OR "equivalence" OR "contamination"

CINAHL search strategy

((MH "Venipuncture") OR (MH "Phlebotomy") OR "venepuncture or venipuncture or phlebotomy") AND ((MH "Catheterization, Peripheral +") OR "catheteri#ation, peripheral" OR "peripheral intravenous catheter" OR "peripheral venous cannula" OR "peripheral venous device" OR "pivc" OR "piv") AND ((MH "Catheter Occlusion +") OR "occlusion" OR (MH "phlebitis+") OR phlebitis OR "dislodgement" OR failure OR "device failure" OR "device malfunction" OR (MH "Catheter-Related Bloodstream Infections") OR (MH "Catheter-Related Infections") OR infection OR "infiltration" OR "extravasation" OR "blockage" OR "leakage" OR "he#molysis of blood samples" OR "he#molysis in blood testing" OR "accuracy in blood test" OR "equivalence in blood tests" OR "contamination of blood cultures")

Cochrane Library

(MH "Phlebotomy") OR "venipuncture*" AND (MH "Catheters") OR "Cannula" or (MH "Catheterization") or (Peripheral Catheterization*) AND "occlusion" OR (MH "phlebitis") OR "dislodge*" OR "failure" OR "infection*" OR "Infiltration" OR "extravasation" OR "blockage" OR "leakage" OR "he#molysis" OR "accuracy" OR "equivalence" OR "contamination"

Scopus

("Phlebotomy" OR "venepuncture") AND ("Catheter*" OR "Intravenous Catheter") AND ("occlusion" OR "phlebitis" OR "dislodge*" OR "failure" OR "infection*" OR "Infiltration" OR "extravasation" OR "blockage" OR "leakage" OR "he#molysis" OR "accuracy" OR "equivalence" OR "contamination")

ISI Web of Science

TS=(Phlebotom* OR Venepuncture* OR Direct Venous Puncture) AND TS=(Catheter* OR Intravenous Catheter* OR Catheteriz*) AND TS=(occlusion OR phlebitis OR dislodge* OR failure OR infection* OR Infiltration OR extravasation OR blockage OR leakage OR hemolysis OR haemolysis OR accuracy OR equivalence OR contamination)

Joanna Briggs (OVID)

(Blood Specimen Collection) OR (Phlebotomy) OR (Venipuncture)) AND (Catheter*) OR (Cannula)) AND ((occlusion OR phlebitis OR dislodge* OR failure OR infection* OR Infiltration OR extravasation OR blockage OR leakage OR hemolysis OR haemolysis OR accuracy OR equivalence OR contamination)

APPENDIX 3

EXCLUDED STUDIES AND REASONS FOR EXCLUSION

Alexandrou, E., Ray-Barruel, G., Carr, P. J., Frost, S., Inwood, S., Higgins, N., Rickard, C. M. (2015). International prevalence of the use of peripheral intravenous catheters. *Journal of Hospital Medicine*, *10*(8), 530-533. https://doi.org/10.1002/jhm.2389

Reason for exclusion: No direct comparison between the groups, PIVC and venepuncture.

Burns, E. R., & Yoshikawa, N. (2002). Hemolysis in Serum Samples Drawn by Emergency Department Personnel versus Laboratory Phlebotomists. *Laboratory Medicine*, *33*(5), 378-380. https://doi.org/10.1309/PGM4-4F8L-2P1M-LKPB

Reason for exclusion: The first part of the study compared ED with non-ED setting – unable to ascertain if the comparison was between PIVC and venepuncture. The second part of the study included paediatric patients.

Carraro, P., Servidio, G., & Plebani, M. (2000). Hemolyzed specimens: a reason for rejection or a clinical challenge? *Clinical Chemistry*, *46*(2), 306-307.

Reason for exclusion: Unclear if they compared between the groups, PIVC and venepuncture.

Cox, S. R., Dages, J. H., Jarjoura, D., & Hazelett, S. (2004). Blood samples drawn from IV catheters have less hemolysis when 5-mL (vs 10-mL) collection tubes are used. *Journal of Emergency Nursing*, *30*(6), 529-533.https://doi.org/10.1016/j.jen.2004.10.004

Reason for exclusion: No direct comparison between the groups, PIVC and venepuncture.

Dugan, L., Leech, L., Speroni, K. G., & Corriher, J. (2005). Factors affecting hemolysis rates in blood samples drawn from newly placed IV sites in the emergency department. *JEN: Journal of Emergency Nursing*, *31*(4), 338-418. https://doi.org/10.1016/j.jen.2005.05.004

Reason for exclusion: No direct comparison between the groups, PIVC and venepuncture.

Dwyer, D. G., Fry, M., Somerville, A., & Holdgate, A. (2006). Randomized, single blinded control trial comparing haemolysis rate between two cannula aspiration techniques. *Emergency Medicine Australasia*, *18*(5-6), 484-488. https://doi.org/10.1111/j.1742-6723.2006.00895.x

Reason for exclusion: No direct comparison between the groups, PIVC and venepuncture.

Everts, R. J., Vinson, E. N., Adholla, P. O., & Reller, L. B. (2001). Contamination of catheter-drawn blood cultures. *Journal of Clinical Microbiology*, *39*(9), 3393-3394. https://doi.org/10.1128/JCM.39.9.3393-3394.2001

Reason for exclusion: Contained data on an excluded group (paediatrics).

Fang, L., Fang, S. H., Chung, Y. H., & Chien, S. T. (2008). Collecting factors related to the haemolysis of blood specimens. *Journal of Clinical Nursing*, *17*(17), 2343-2351. https://doi.org/10.1111/j.1365-2702.2006.02057.x

Reason for exclusion: Contained data on an excluded group (paediatrics).

Prue-Owens, K. (2006). Use of peripheral venous access devices for obtaining blood samples for measurement of Activated Partial Thromboplastin Times. *Critical Care Nurse*, *26(1)*, 30–38.

Reason for exclusion: Data analysis did not include Bland–Altman plots.

Straszewski, S., Sanchez, L., McGillicuddy, D., Boyd, K., DuFresne, J., Joyce, N., . . .Mottley, J. (2011). Use of separate venipunctures for IV access and laboratory studies decreases hemolysis rates. *Internal and Emergency Medicine*, *6*, 357-359.

Reason for exclusion: This study evaluated a policy change – we were unsure if in the baseline data collection if blood could have been collected by either venepuncture or from a PIVC.

Zengin, N., & Enç, N. (2008). Comparison of two blood sampling methods in anticoagulation therapy: venipuncture and peripheral venous catheter. *Journal of Clinical Nursing*, *17*(3), 386-393. https://doi.org/10.1111/j.1365-2702.2006.01858.x

Reason for exclusion: Data analysis did not include mean difference and Bland–Altman plots.