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Original Article

Catheter-related bloodstream infections in hemodialysis: a systematic review and meta-analysis of prevalence and risk

Raja A Aftab[1], Vincent MAL Mariadass[1], Syireen B Alwi[1], Baharudin B Ibrahim[1], Lim S Kun[2], Lam J Kai[1], Zirwa A Butt[1]

[1] *Department of Clinical Pharmacy and Pharmacy Practice, Faculty of Pharmacy, Universiti Malaya, Malaysia*
[2] *Department of Medicine, Faculty of Medicine, Faculty of Medicine, Universiti Malaya, Malaysia*

Abstract

Introduction: This study aims to identify and systematically assess the prevalence of Catheter-related bloodstream infections (CRBSI) and identify risk factors of CRBSI in hemodialysis (HD) patients.

Methodology: A comprehensive literature review was conducted to identify pertinent studies related to the prevalence of CRBSI and risk factors of CRBSI in HD patients. This involved searching widely recognized electronic databases with MeSH terms to retrieve relevant studies. Relevant articles were screened, duplicates were removed, eligibility criteria were applied, and studies that met the criteria were reviewed. Prevalence of CRBSI was pooled using a random effect model using Comprehensive Meta-Analysis (CMA) software.

Results: From the initial search across four electronic databases, a total of 1850 studies were identified. After eliminating 1615 duplicate studies, 235 remained for screening. Of these, 180 were excluded due to the lack of relevant terms. Of the 55 studies left, 43 were not included due to a lack of relevant data. Finally, the pooled combined prevalence across these 12 studies was 22.8% (95% CI of 0.117 to 0.397), whereas the I-squared value obtained is 99.38%. Regionally, prevalence in Asia was 17.5% (95% CI of 0.046 to 0.483), while in Africa it was 30.4% (95% CI of 0.240 to 0.376). The most common risk factors identified were immunocompromised status, along with comorbidities such as hypertension and diabetes mellitus, previous catheter insertion, and prolonged hospital stays.

Conclusions: The findings of this review indicate that CRBSI is a serious issue faced by HD patients, especially those with the commonly identified risk factors.

Key words: prevalence; risk factor; catheter related bloodstream infection; hemodialysis.

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Introduction

Kidney transplantation is often considered the optimal treatment for patients with end-stage renal disease (ESRD), offering the potential for improved quality of life and survival rates. However, not all patients are suitable candidates for transplantation due to factors such as comorbidities, lack of available donors, and other contraindications. As a result, hemodialysis remains a critical and more sustainable treatment option for many ESRD patients. Hemodialysis involves the use of vascular access to facilitate the exchange of fluids and toxins from the bloodstream. Central venous catheters (CVCs) are commonly used as temporary access points for hemodialysis, but in some cases, they serve as long-term solutions when other access types are not viable [1]. Despite their utility, CVCs present a significant risk for catheter-related bloodstream infections (CRBSIs) due to their partial external placement, which allows microorganisms from the skin to enter the bloodstream along the catheter line [2,3].

CRBSIs have profound implications for patients, affecting physical health, mental well-being, and financial stability [4]. Mortality rates associated with CRBSIs are concerning, with reports indicating 1,000 to 1,300 deaths annually in Germany, accounting for 12% to 15% of CRBSI cases [5]. Similarly, Italy reported 1,450 deaths out of 8,500 CRBSI cases, while Korean hospitals documented 29 deaths among 80 patients with CRBSIs [6]. The financial burden of CRBSIs is substantial, impacting both healthcare systems and individuals. In Germany, the cost of treating a single episode of CRBSI is estimated at €4,200, with average costs exceeding €13,035, leading to a total expenditure of €81.6 million for the healthcare system [7]. The extended hospital stays required for CRBSI treatment contribute to a 9% increase in average costs [2].

Central venous catheters (CVCs) significantly contribute to catheter-related bloodstream infections (CRBSIs), but they are not the only risk factor. Several other potential risk factors can increase the likelihood of CRBSIs. These include underlying health conditions, the method of catheter insertion, and the duration of

catheterization [8]. The use of intravascular catheters for administering parenteral nutrition is also associated with an elevated risk of CRBSIs [9]. Local factors such as poor personal hygiene, occlusive transparent dressings, moisture around the catheter exit site, and nasal colonization by *Staphylococcus aureus* further exacerbate the risk of CRBSIs [10]. Additional risk factors specific to dialysis-related CRBSIs include contamination of dialysate or equipment, inadequate water treatment, and dialyzer reuse. Patient-related factors, such as older age, higher doses of intravenous iron, increased doses of recombinant human erythropoietin, lower hemoglobin and serum albumin levels, diabetes mellitus, peripheral atherosclerosis, and recent hospitalization or surgery, also contribute to an increased risk [2,8,11,12]. These complexities underscore the need for a systematic review to identify the overall prevalence and key risk factors of CRBSI to develop targeted prevention and management strategies.

Thereby, this systematic review and meta-analysis aim to comprehensively examine the literature to understand the prevalence of CRBSIs and identify associated risk factors among hemodialysis patients. The insights gained from this review are expected to be valuable in clinical practice, helping to inform strategies to reduce CRBSI rates and ultimately improve patient outcomes.

Methodology

All articles related to the prevalence of and risk factors associated with CRBSI among hemodialysis patients, which were published on online databases as scientific literature, were systematically identified. The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines were adhered to strictly while conducting the literature search and reporting of the results. The protocol of this systematic review has been registered under PROSPERO (CRD42024510699).

Data Sources and Search Strategy

The complete systematic search for articles published on prevalence and risk factors associated with CRBSI among hemodialysis patients on the online databases of PubMed, Science Direct, Scopus, and Google Scholar. The MeSH words such as *prevalence, popularity, commonness, predominance, risk factors, threat, danger, hazard, catheter-related infections, renal dialysis,* and *central venous catheter* were used to search and were performed through the title and abstract only. Specifically for PubMed, the Boolean search of ((“Prevalence” [MeSH]) OR (“Risk Factors” [MeSH]) AND (“Renal Dialysis” [MeSH] OR “Central Venous Catheter” [MeSH])) was implemented. The search was limited to results of clinical trials and articles published in English.

Inclusion/Exclusion Criteria

All the articles on the prevalence and risk factors of CRBSI in hemodialysis patients published were included in this review. Moreover, only articles mentioning the usage of CVC as the hemodialysis access were included, while any articles using AVF or AVG were excluded. Similarly, articles highlighting patients hospitalized due to CRBSI were included. Systematic literature reviews, abstracts. Scientific correspondence, posters, animal studies, case reports, advertisements, theses, and opinions were excluded. Similarly, studies published in languages other than English were excluded. All the selected articles were independently reviewed to meet the inclusion and exclusion criteria.

Data Selection and Extraction

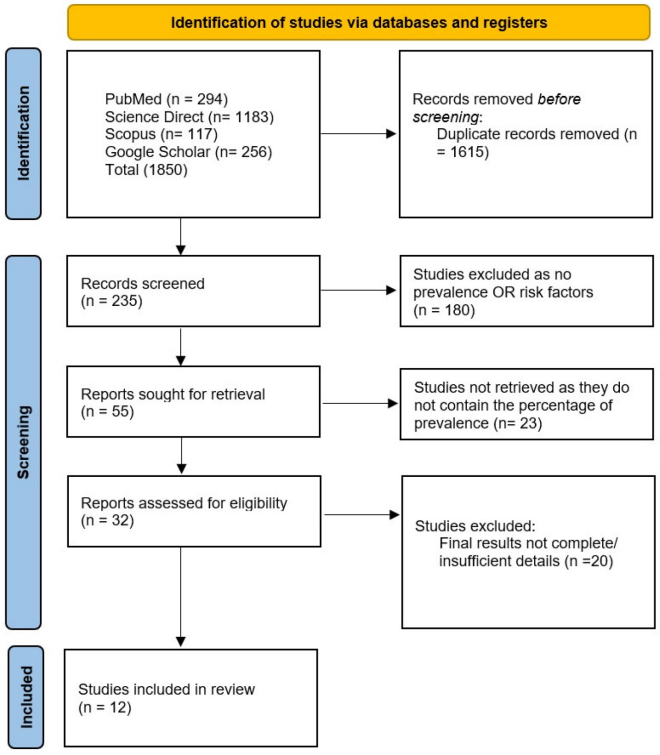
All the selected articles were retrieved after the preliminary search and imported into the Mendeley software. A total of 1,615 duplicate articles were identified and removed using Mendeley’s automatic duplicate-detection feature, which recognizes identical titles, authors, and publication years across databases. These duplicates originated from the same studies retrieved from multiple databases. All the duplicate articles were removed, and further assessment of the articles was carried out for eligibility through the screening of titles and abstracts by all seven authors independently. A full-text assessment was done for the final selection of articles. Any disagreements on the selection and eligibility of the studies were resolved through discussion. The final study selection was accepted for the review and meta-analysis. The selected study was rechecked for the validation of the screening procedure.

Upon final selection, a data extraction form was created in order to retrieve all the relevant information. This included the authors’ names, year, and the region of the study, along with the sample size and prevalence of CRBSI. Data on risk factors, microorganisms involved, and the interventions provided, along with the outcomes compromising either survival or mortality, were also extracted. This information in the data extraction form was finalized upon mutual agreement.

Risk of Bias (Quality Assessment)

The Newcastle Ottawa scale (NOS) was used for the risk of bias (quality assessment) as it is the most suitable for observational studies. According to the NOS, stars are awarded for 3 categories, which are "Selection", "Comparability", and "Outcome", and each of these 3 categories is divided into different subcategories. A maximum of 1 star can be awarded to each study in the following subcategories, but for the "Comparability" category, a maximum of 2 stars can be given. In total, a maximum number of 9 stars can be obtained for a single study, which indicates the absence of any bias, hence ensuring the quality [13]. NOS is then later converted to Agency for Healthcare Research and Quality (AHRQ) standards under the classification of good, fair, and poor for the final quality assessment of the studies. This means that the number of stars for each study is equivalent to good, fair, or poor, indicating the quality. Any studies with 3 or 4 stars in "Selection", 1 or 2 stars in "Comparability", and 2 or 3 stars in "Outcome" will be identified as a good study. As for the fair classification, a study must have 2 stars in "Selection", 1 or 2 stars in "Comparability", and 2 or 3 stars in "Outcome" whereas for the poor classification, a study must have 0 or 1 stars in "Selection", 0 stars in "Comparability" and 0 or 1 stars in "Outcome". All seven authors independently assessed the risk of bias, and the decision of the study quality and eligibility of studies was based on mutual agreement.

Figure 1. Schematic diagram showing the assortment and study selection process (PRISMA Flow).



Strategy for Data Synthesis

A complete systematic review was performed to ensure all the data synthesis was obtained from the highest possible and complete collection of the literature. Quantitative synthesis or meta-analysis was performed using the Comprehensive Meta-Analysis (CMA) software. The prevalence and relative risk (RR) were calculated with a 95% confidence interval (CI). Subgroup analysis based on the regions, such as Asia and Africa, along with the prevalence reported in the included studies, was performed. Heterogeneity between studies was assessed using the I^2 statistic. A fixed effect model was used when $I^2 < 50\%$, which indicated the heterogeneity. Similarly, if $I^2 > 50\%$, a random effects model was used after consideration of the potential sources of heterogeneity.

Results

At first, 1850 articles were identified in total from all the online databases. 1183 of the articles were from ScienceDirect, 294 from PubMed, 117 from Scopus, and 256 from Google Scholar. Unfortunately, 1615 of the articles were duplicates, hence removed. The remaining 235 articles were screened, of which 180 articles were excluded. Then, 55 articles were retrieved, and 23 of those articles were removed due to being unable to meet the inclusion criteria. The remaining 32 articles were then assessed for eligibility, and 20 articles were removed. Finally, a total of 12 articles were selected for this review as they met the requirements of the inclusion criteria with all the relevant information (Figure 1).

Evaluation of Study Quality

The quality rating of all the studies in this review was good, with 5 of the studies having a score of 8, while the remaining had a score of 7. As the NOS was divided into 3 different groups, all the articles scored 1 star under the selection group, which comprises 4 different subgroups. Whereas under the comparability group, similar to what has been mentioned, all the articles scored 1 star too. Only under the outcome's groups, which were further divided into 2 groups, where only 5 articles scored 2 stars, whereas the remaining articles only scored 1 star. Hence, the assessment of the outcome subgroup was the main deciding factor; all the articles also scored 1 star under the statistical test subgroup. Table 1 shows the detailed quality of the scoring of the studies.

Table 1. Quality assessment using the Newcastle Ottawa Scale

Author, Year	Selection				Comparability of different outcome groups	Outcome		Total quality scores	Quality rating according to guidelines
	Representativeness of the sample	Sample size justified/not justified	Ascertainment of the exposure (Prevalence)	Ascertainment of the exposure (Risk factor)		Assessment of the outcome	Statistical test		
Wu Y-L *et al.*, 2020 [12]	*	*	*	*	*	**	*	8	Good
Shamira Shahar *et al.*, 2021 [13]	*	*	*	*	*	**	*	8	Good
Opoku-Asare. B *et al.*, 2023 [9]	*	*	*	*	*	*	*	7	Good
Thompson. S *et al.*, 2017 [14]	*	*	*	*	*	**	*	8	Good
Nawi *et al.*, 2015 [15]	*	*	*	*	*	*	*	7	Good
P. Pandit *et al.*, 2019 [16]	*	*	*	*	*	*	*	7	Good
F. Bello., 2022 [17]	*	*	*	*	*	*	*	7	Good
Khan, M. A. R. *et al.*, 2023 [18]	*	*	*	*	*	*	*	7	Good
Borges, P. de R. R., & Bedendo, J., 2015 [19]	*	*	*	*	*	**	*	8	Good
Sanavi S *et al.*, 2007 [20]	*	*	*	*	*	*	*	7	Good
Delistefani F *et al.*, 2019 [1]	*	*	*	*	*	**	*	8	Good
Tarek A. Ghonemy *et al.*, 2016 [21]	*	*	*	*	*	*	*	7	Good

*NOS rating conversion to AHRQ standards (good, fair, and poor): For good quality, a study must have 3 or 4 stars, 1 or 2 stars, and 2 or 3 stars in 'Selection', 'Comparability', and 'Outcome' domains, respectively. For fair quality, a study must have 2 stars, 1 or 2 stars, and 2 or 3 stars in 'Selection', 'Comparability', and 'Outcome' domains, respectively. For poor quality, a study must have 0 or 1 star, 0 star, or 0 or 1 star in 'Selection', 'Comparability', and 'Outcome' domains, respectively. A maximum of one star can be awarded for each subcategory within the Selection and Outcome categories. A maximum of two stars can be awarded for the Comparability category.

Characteristics of the Selected Studies

The major characteristics of the 12 studies included in this review are described in Table 2. There were 2 studies conducted in Malaysia, while the remaining were one each in China, Ghana, Canada, India, Nigeria, Bangladesh, Brazil, Iran, Germany, and Egypt. Hence, a total of 6 studies were conducted in Asia, and 3 studies were conducted in Africa, along with 2 studies conducted in America, and only 1 study was conducted in Europe. From the selected 12 studies, a cross-sectional study was utilized by 5. The remaining 7 studies each implemented retrospective and prospective study designs. The sample size involved in the studies was in a similar variation, ranging from 80 to 180 participants. Only 3 studies were outside the range as the sample size was 7393, 1131, and 1898 [14,16,18].

Out of the 12 studies reviewed, *Staphylococcus aureus* was common in 8 of the studies [11,12,14,16,17,19,20,22]. Only Pandit *et al.* [18] and Delistefani *et al.* [1] reported Methicillin-resistant *Staphylococcus aureus* (MRSA), whereas Shahar *et al.* [15] reported the presence of Methicillin-susceptible *Staphylococcus aureus* (MSSA) along with Methicillin-resistant coagulase-negative *Staphylococci* (MRCONS). Along with these microorganisms, the presence of *Pseudomonas aeruginosa, Escherichia coli, Acinetobacter baumannii, Klebsiella ozaenae,* and *Klebsiella pneumoniae* was reported in the studies [12,19-22]. The treatment given to the patients from the studies reviewed was the administration of antibiotics either orally or intravenously (IV). Sanavi *et al.* [12] recorded the use of Vancomycin and Amikacin in the study, whereas Delistefani *et al.* [1] reported MRSA eradication as the intervention. Shahar *et al.* [15] and Thompson *et al.* [16] reported the catheter removal as the primary management, while Opoku-Asare *et al.* [11] reported the implementation of skin asepsis, which is done using 2% aqueous chlorhexidine glucuronate together with 70% isopropyl alcohol.

Among the 12 reviewed studies, six explicitly reported the use of antibiotics as part of the intervention for CRBSI management [1,12,14,15,19,21]. Vancomycin and amikacin were administered in the study by Sanavi *et al.* [12] for treating *Staphylococcus aureus* and *E. coli* infections, whereas Wu *et al.* [14] reported both intravenous and oral antibiotics, which were associated with a reduction in hospital stay. Similarly, Shahar *et al.* [15] described the use of systemic antibiotics alongside catheter removal, achieving 35% catheter salvage and a low mortality rate (1%).

In contrast, Delistefani *et al.* [1] emphasized the use of prophylactic or prolonged antibiotic therapy for MRSA eradication, but despite this approach, they reported a mortality rate of 14.6%. Borges and Bedendo [21] implemented empirical antibiotic therapy for *Pseudomonas aeruginosa*, *Acinetobacter baumannii*, and *Klebsiella ozaenae*, yet recorded the highest mortality (54.2%) among all studies, suggesting variable treatment response. Bello [19] also noted

Table 2. Characteristics of studies included.

Author, Year	Study design	Sample size	Prevalence (%)	Risk factor	Vascular access type	Microorganism	Intervention	Outcomes	Region
Wu Y-L *et al.*, 2020 [14]	Prospective	7393	2.99	> 2 daily dialysis session [0.88 (95% CI 0.59-1.33, p = 0.545)], female [1.61 (95% CI 1.07-2.41, p0.023)], > 70 years old [1.68 (95% CI 1.04-2.69, p = 0.033)], duration of therapy: 1-5 years [1.08 (95% CI 0.64-1.83, p = 0.771)] & > 5 years [0.91 (95% CI 0.51-1.64, p = 0.756)]	Fistula 85.3%; Graft 0.4%; Tunneled central line 12.7%; Non-tunneled central line 1.2%; Other 0.3%	*Staphylococcus aureus*	IV & Oral antibiotic	Reduction in hospital stay, discharge from hospital & no mortality	China
Shamira Shahar *et al.*, 2021 [15]	Retrospective	82	4.2	History of previous catheter infection (p = 0.145), ischaemic heart disease (p = 0.571), hypertension (p = 0.770) & diabetes mellitus (p = 0.648).	**CRBSI cohort** tunneled 77%. non-tunneled 23%. **Catheter colonization cohort** tunneled 88%, non-tunneled 12%	MSSA & MRCONS	Catheter removal & Systemic antibiotics	8% ICU admission, 1% mortality, 35% catheter salvage, 2% metastatic infection, 28% recurrent CRBSI & 18% septic shock	Malaysia
Opoku-Asare. B *et al.*, 2023 [11]	Cross-sectional	152	34.2	Longer dependence of central venous catheter access, impaired immunity, low haemoglobin level, low serum albumin level, diabetes mellitus and peripheral atherosclerosis (p < 0.05)	-	*Staphylococcus aureus*	Skin asepsis (2% aqueous chlorhexidine glucuronate + 70% isopropyl alcohol)	No mortality	Ghana
Thompson. S *et al.*, 2017 [16]	Prospective	1131	23.34	Substance misuse, chronic liver disease, peripheral vascular disease & hypertension. [(RR) 2.32 (95% CI 1.40, 3.83), 1.98 (95% CI 1.20, 3.27), 1.70 (95% CI 1.11, 2.59), and 1.38 (95% CI 1.04, 1.82), respectively. Only chronic liver disease was associated with the rate of CRBSI: RR 2.11 (95% CI 1.15, 3.86)]	-	*Staphylococcus aureus*	Catheter removal	Improved quality of living & no mortality	Canada
Nawi *et al.*, 2015 [17]	Retrospective	116	19	Duration of hospital admission, duration of catheterization & HbA1c level. [(adjusted OR:1.118 (95% CI: 1.030, 92.805), p = 0.004), (adjusted OR: 0.965 (95% CI 0.939, 0.992), p = 0.005) & (i) HbA1c 6.6-8.0% (adjusted OR: 1.143 (95% CI: 0.249,5.247), p = 0.849) and ii) HbA1c ≥ 8.0% (adjusted OR: 5.613 (95% CI 1.023, 30.792), p = 0.047)]		*Staphylococcus aureus*	Nil	No mortality	Malaysia
P. Pandit *et al.*, 2019 [18]	Prospective	1898	39.25	Immunocompromised patients & catheterisation time (p < 0.0001 & < 0.0402)	**CRBSI** 212; Central venous catheter 107; Peripherally inserted central catheter 7; Peripheral venous catheter 98 (Excluded)	MRSA	Nil	No mortality	India

Table 2 (continued). Characteristics of studies included.

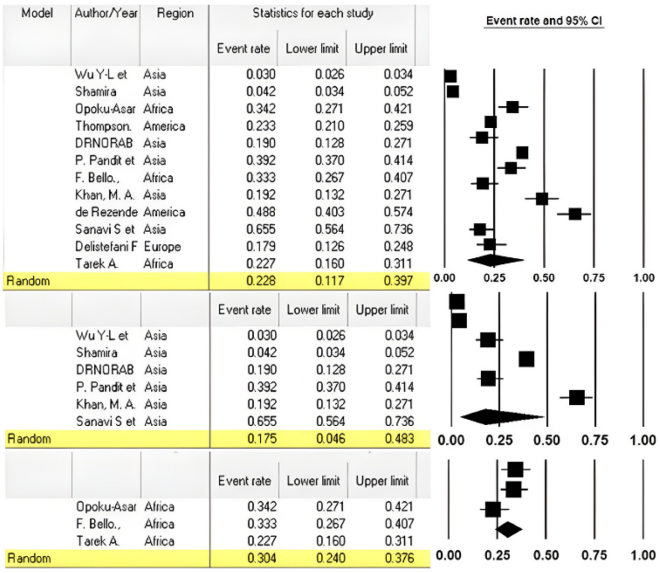
Author, Year	Study design	Sample size	Prevalence (%)	Risk factor	Vascular access type	Microorganism	Intervention	Outcomes	Region
F. Bello., 2022 [19]	Cross-sectional	171	33.33	Diabetes, fever, > 180 CVC days, low serum albumin & high white cell count. [1.268 (95% CI 1.087 - 4.831, p = 0.023), 1.232 (95% CI 0.072 -2.747, p = 0.014), 1.759 (95% CI 1.239 – 3.414, p = 0.041), 5.6 (95% CI 1.879 - 16.723, p = 0.002) & 3.287 (95% CI 1.212 – 8.912, p = 0.019)]	-	*Staphylococcus aureus, Pseudomonas aeruginosa & Escherichia coli*	Nil	No mortality	Nigeria
Khan, M. A. R. *et al.*, 2023 [20]	Prospective	125	19.2	Diabetes mellitus (p = 0.001), hypertension (p = 0.050), previous haemodialysis catheterization within past 2 months (p = 0.096) and previous haemodialysis catheterization 2 months prior (p = 0.217)	Jugular venous catheter 18.4%; Femoral venous catheter 22%; Peripheral central catheter 12.5%	*Pseudomonas aeruginosa, Staphylococcus aureus & Escherichia coli*	Nil	No mortality	Bangladesh
Borges, P. de R. R., & Bedendo, J., 2015 [21]	Cross-sectional	129	48.84	Colonization of catheter, lengthy hospital stays, number of haemodialysis session & diabetes mellitus	Temporary catheters	*Pseudomonas aeruginosa, Acinetobacter baumanni & Klebsiella ozaenae*	Empirical antibiotic	54.17% mortality	Brazil
Sanavi S *et al.*, 2007 [12]	Cross-sectional	116	66	41% was diabetic with history of previous catheter placement & 32% with history of catheter associated infections	Temporary catheters	*Staphylococcus aureus (42%), Coagu-lase-negative staphylococci (20%), E. coli (19%), Enterococci (7%), Streptococci D (7%), Pseudomonas aeruginosa (4%), klebsiella pneumoniae (1%)*	Vancomycin & Amikacin	No mortality	Iran
Delistefani F *et al.*, 2019 [1]	Retrospective	151	17.9	Diabetes mellitus (p = 0.64), immunosuppression (p = 0.71), MRSA-carriage (p < 0.001), previous catheter-related infection (p < 0.05), catheter removal or revision (p = 0.002), rehospitalization (p = 0.001) and use of antibiotics (p = 0.02).	Permanent dialysis catheter	MRSA	MRSA eradication, prophylactic/longer treatment with antibiotics	14.57% mortality	Germany
Tarek A. Ghonemy *et al.*, 2016 [22]	Cross-sectional	119	22.7	29% Stenosis, 17% diabetes mellitus and 14% hypertension	-	*Staphylococcus aureus, Pseudomonas aeruginosa & Klebsiella pneumoniae*	Nil	No mortality	Egypt

antibiotic usage for Sta*phylococcus aureus, Pseudomonas aeruginosa,* and *Escherichia coli,* although outcome improvement was not statistically detailed.

The overall prevalence of all 12 studies in this review is 22.8% (0.228 with a 95% CI of 0.117 to 0.397), whereas the I-squared value obtained is 99.38% (Figure 2). The highest prevalence noticed was from Sanavi *et al.* (2007, with a prevalence of 65.5% (0.655 with a 95% CI of 0.564 to 0.736), whereas the lowest prevalence was noticed by Wu *et al,* having a prevalence of 3% (0.030 with a 95% CI of 0.026 to 0.034). As for the subgroup analysis, 2 groups of Asia and Africa were used for the analysis. There was a total of 6 studies in this review from the Asia region, hence the overall prevalence of these studies is 17.5% (0.175 with a 95% CI of 0.046 to 0.483) while there were 3 studies from the Africa region in which the overall prevalence of the studies is 30.4% (0.304 with a 95% CI of 0.240 to 0.376).

Figure 3 shows the funnel plot for publication bias that suggests studies appear asymmetrical, with more

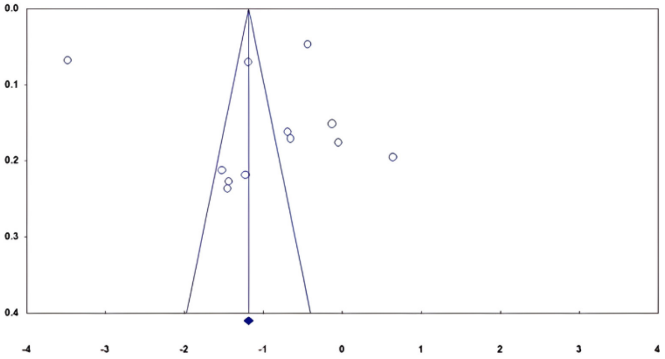
Figure 2. Overall meta-analysis of the prevalence of CRBSI among hemodialysis patients.



studies on the right side of the mean effect size, suggesting a potential publication bias among the studies.

Figure 4 illustrates the global prevalence of CRBSI per 10,000 hemodialysis patients, highlighting the significant geographical variations. Asia has the highest prevalence, particularly in Iran, with around 6,000 per 10,000 patients. Africa and South America also have a noticeable prevalence of CRBSI (Figure 3).

Figure 3. Funnel plot publication biases.

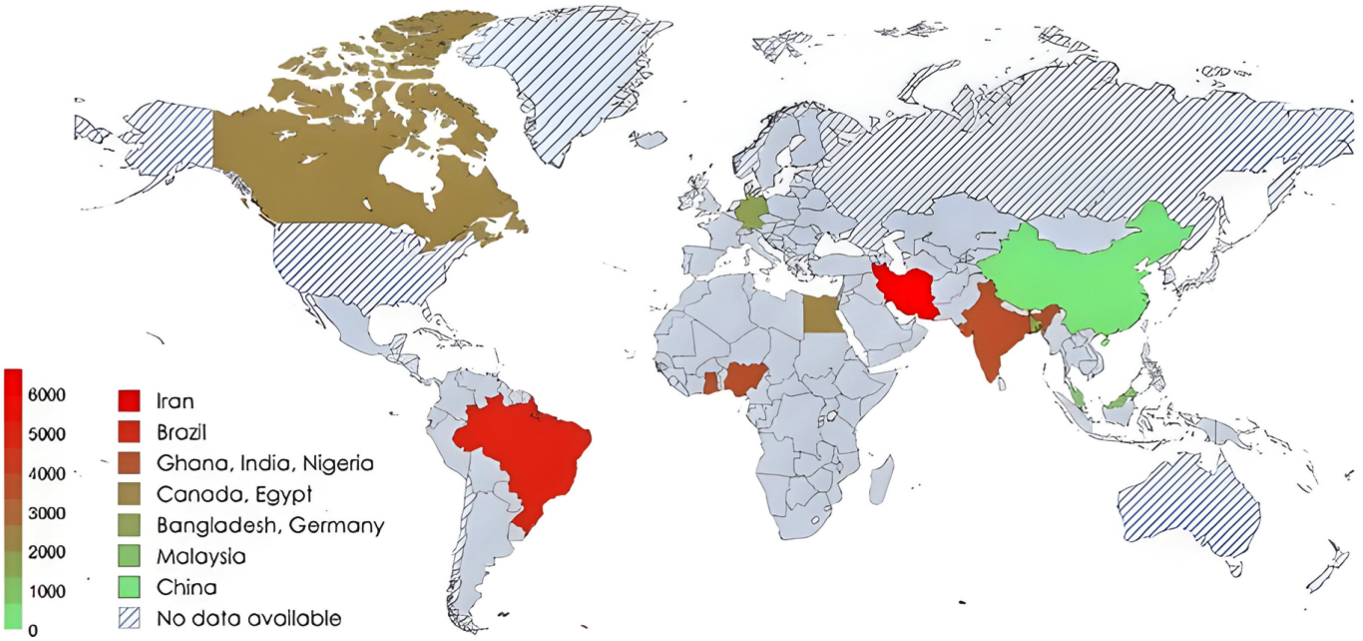


Discussion

The comprehensive search strategy applied in this review identified a total of 12 studies that described the prevalence and risk factors of CRBSI among hemodialysis patients, along with other relevant information such as the microorganisms involved, the management done, and the final outcomes of the patient. All the results of this study had a positive correlation with the risk factors and the occurrence of CRBSI among hemodialysis patients.

Central line-associated bloodstream infections are a significant concern among HD patients, especially among patients with co-morbid conditions. Studies have reported that patients with diabetes are at a higher risk of developing CRBSI infections compared to patients who do not have diabetes [23]. The increase in risk of infections can be attributed to several factors, including poor glycemic control. Poorly controlled

Figure 4. The global prevalence of CRBSI per 10,000 hemodialysis patients.



diabetes can lead to a compromised immune system, making patients more susceptible to infections. Additionally, the hyperglycemic environment created by uncontrolled diabetes can provide a conducive environment for the growth of microorganisms, further increasing the risk of central line-associated bloodstream infections.

Furthermore, diabetic patients on hemodialysis have been found to have higher rates of mortality and morbidity due to central line-associated bloodstream infections [19]. This is likely due to the combination of factors, such as increased blood viscosity, faster protein breakdown, and reduced immunoglobulin and antibody production, all of which can contribute to the development and severity of these infections.

Similarly, Patients with hypertension are considered a high-risk group for infection [15,16,20]. This is partly due to the difficulty in controlling elevated blood pressure during dialysis. Factors such as volume overload and sodium retention are likely major pathogenic pathways [24]. Still, increased arterial stiffness and the activation of the renin-angiotensin-aldosterone system (RAAS) may also play significant roles. These physiological changes can impact the immune system, as RAAS activation promotes macrophage phagocytosis, leading to the secretion of cytokines and chemokines [11].

Patients undergoing hemodialysis face a significant risk of in-hospital exposure due to various factors, including excessive cytokine secretion, hypertension, and the extended use of hemodialysis catheters [8,25,26]. Cytokine storms and impaired cellular and humoral immunity can increase pathogen virulence, while the prolonged use of catheters leads to heightened exposure to environmental pathogens and a higher risk of catheter-related bloodstream infections [2,25].

Although the duration of hemodialysis is not a modifiable factor, addressing other risk factors is crucial to reducing the infection risk. The frequency of hemodialysis sessions and the length of hospital stay are identified as risk factors in this analysis. Length of hospital stay directly increases patients' exposure to pathogens, making them more susceptible to infection. Moreover, factors such as low educational level, low family income, inadequate hand hygiene, and lack of a sink in the dialysis room have been identified as potential risk factors for a higher frequency of peritonitis and hospitalizations [27].

CRBSI is also caused by catheter-related factors such as the catheter frequency and catheter indwelling time [17-19,21]. The higher the number of catheterizations leads to higher the possibility of CRBSI occurrence. This is due to the multiple punctures done to the vascular wall, hence damaging it and affecting the skin around. The catheter used for multiple hemodialysis sessions can be involved in four different pathogenic pathways: colonization of the catheter tip and cutaneous tract with skin flora; colonization of the catheter lumen caused by contamination; hematogenous seeding of the catheter from another infected site; and contamination of the lumen of the catheter with infusate [21]. Reduction of the use of catheters will help prevent the increase of infections, and patient education should be carried out. The Center for Disease Control (CDC) has recommended hand hygiene, patient and staff education, along with skin antisepsis to decrease the risk of CRBSI. Lastly, age is also a risk factor that increases the rate of infection, especially in elderly patients on hemodialysis [14]. These patients tend to have impaired immune response as they suffer from comorbidities, hence allowing an easier route for the microorganisms [18]. Therefore, elderly patients with significantly impaired immune systems are at risk of CRBSI.

The results of the overall meta-analysis of the 12 studies indicated that there is a 22.8% chance of occurrence for CRBSI among hemodialysis patients. The obtained I-squared value explains that the observed effect reflects variance in true effects rather than sampling error. The subgroup analysis of Asia indicated that there is a 17.5% chance of occurrence for CRBSI in hemodialysis patients among the Asian region, whereas for the African subgroup is equivalent to 30.4% chance of occurrence for CRBSI in hemodialysis patients among the African region. It is noted that the African region is more prone to CRBSI than the Asian region, as the WHO has characterized Africa as the largest infectious disease burden [28]. This is due to the weakened public health infrastructures, hence posing a threat to global health security. Despite the success of vaccination programs for polio and childhood diseases, other infections, including CRBSI, still cause high mortality rates [29]. However, the rate of mortality only provides a partial understanding of infectious disease, as the global burden includes disabilities, deformities, loss of productivity, and lack of treatment options for the measurement of health impact.

While this systematic review offers valuable insights into the prevalence and risks of catheter-related bloodstream infections (CRBSI) in hemodialysis patients, there are certain limitations to consider. One key limitation is the absence of subgroup analysis based on catheter type, such as tunneled versus non-tunneled

or femoral versus jugular insertion sites. Although we acknowledge that different catheter types may affect infection risk, the included studies did not consistently report this information, making it challenging to perform meaningful comparisons without introducing bias. Likewise, data on catheter locking solutions, which play a vital role in infection prevention, were often unavailable, preventing us from evaluating their impact on CRBSI rates. Another limitation is the incomplete reporting on the timing of infections after catheter insertion, which could have provided further insights into early versus late bloodstream infections. Despite these challenges, this review highlights significant trends and risk factors associated with CRBSI, emphasizing the need for future studies with standardized reporting on catheter characteristics and infection timing to enhance infection prevention strategies.

Conclusions

This systematic review and meta-analysis highlight the prevalence of CRBSI among HD patients and identify key risk factors that contribute to this complication. The pooled prevalence of CRBSI was estimated to be 22.8%, with notable regional differences observed, such as a higher prevalence in Africa compared to Asia. Immunocompromised status, comorbidities like hypertension and diabetes mellitus, prior catheter insertions, and extended hospital stays emerged as the most prevalent risk factors associated with CRBSI. These findings underscore the urgent need for targeted interventions and strategies to mitigate these risks and reduce the incidence of CRBSI in HD patients. Enhancing infection control measures, especially for high-risk individuals, and focusing on modifiable factors can play a crucial role in improving patient outcomes. Further research is warranted to develop and implement effective prevention and management strategies tailored to different regional contexts and healthcare settings.

Corresponding author

Dr Raja Ahsan Aftab
Department of Clinical Pharmacy and Pharmacy Practice,
Faculty of Pharmacy, Universiti Malaya,
50603 Kuala Lumpur, Malaysia
Tel: +60 172554387
Email: ahsan1025@yahoo.com
ORCID iD: 0000-0002-9280-1264.

Conflict of interest

No conflict of interest is declared.

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