BJCMR Brazilian Journal of Clinical Medicine and Review

PCAA PUBLICAÇÕES CIENTÍFICAS DE ACESSO ABERTO

Original Article

Patients with Acute Kidney Injury Undergoing Hemodialysis: Epidemiology and Factors Associated with Catheter-Related Bloodstream Infection

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Abstract: Acute kidney injury (AKI) has a high mortality rate, especially when hemodialysis (HD) is required. Catheter-related bloodstream infection (CRBSI) is a reported complication, with Staphylococcus aureus as the main causative agent. The objectives of this study were to analyze the epidemiological profile of patients undergoing HD for AKI and to identify CRBSI characteristics and outcomes. This was an observational, retrospective study of patients with AKI undergoing HD via non-tunneled double-lumen catheters (LCLC) during hospitalization. Clinical, microbiological, and HD-related data were collected. A total of 290 patients were included (65.9% male; mean age 62.2 ± 2 years); 26.9% were septuagenarians, 49.3% hypertensive, and 35.9% diabetic. Sepsis-related AKI was the leading etiology (33.4%); the mean number of HD sessions was 4.9 ± 3.6 per patient. The incidence of CRBSI was 14.5%; S. aureus was the main agent (30%; 46% MRSA), followed by A. baumannii (9.6%). There was no association between sex, age, or NTDLC insertion site and CRBSI. A higher incidence of CRBSI was observed among those who underwent a greater number of HD sessions ($p<0.001$). Overall mortality was 54.5%. AKI requiring HD is associated with high mortality, and CRBSI is frequent. The prevalence of elderly patients and multidrug-resistant bacteria in the sample studied is noteworthy.

Keywords: Acute Kidney Injury; Hemodialysis; Catheter-Related Infection.

Citation: Silva GS, Ciesielski TS, Carneiro JLS, Monich AG, Romani RF. Patients with Acute Kidney Injury Undergoing Hemodialysis: Epidemiology and Factors Associated with Catheter-Related Bloodstream Infection. Brazilian Journal of Clinical Medicine and Review. 2026: Jan-Dec; 04(1):bjcmr40.

https://doi.org/10.52600/2763-583X.bjcmr.2026.4.1.bjcmr40

Received: 3 July 2025
Accepted: 8 September 2025
Published: 10 September 2025

1. Introduction

Acute kidney injury (AKI) is defined as a rapid decline in renal function and is a common complication in hospitalized patients, particularly in intensive care units (ICUs). It is responsible for high mortality rates and substantial healthcare costs [1–3]. It is estimated that AKI occurs in approximately 13.3 million patients annually [4], and the long-term effects of AKI remain uncertain due to the lack of longitudinal and prospective studies. Irreversibility of AKI is estimated to occur in approximately 5% of cases, reaching up to 16% in elderly patients, potentially leading to the development of chronic kidney disease [5]. When AKI requires renal replacement therapy (RRT) via dialysis, mortality rates can reach 55% [6].

In cases of AKI requiring urgent hemodialysis (HD), the most frequently used vascular access is the non-tunneled double-lumen catheter (NTDLC) [7]. It is recommended to maintain this type of catheter for up to 2 weeks; however, due to the absence of a protective cuff, it has a higher incidence of catheter-related bloodstream infections

(CRBSI) [7,8]. The incidence of CRBSI varies between 0.6 and 6.5 episodes per 1000 catheter-days, with Staphylococcus aureus being the main causative agent [9]. The association between catheter insertion site and CRBSI remains controversial: some studies report a higher incidence when the catheter is placed in femoral veins, while others do not find this association [9–14].

Although most of the global population lives in developing countries, most epidemiological data on AKI patients come from developed countries [15]. Understanding the epidemiological profile of patients with AKI and the incidence and microorganisms associated with CRBSI in developing countries is essential to implement preventive measures and reduce these events. The objective of this study is to determine the incidence of AKI requiring urgent HD and the epidemiological characteristics of patients in a university hospital in southern Brazil, as well as to identify factors associated with the occurrence of CRBSI.

2. Methods

2.1 Study Design

This was an observational, descriptive, retrospective, cross-sectional study with a quantitative approach, conducted using electronic medical record data from patients admitted to a tertiary care hospital, a reference center for nephrology, in Curitiba (PR, Brazil) from March to December 2023. Patients over 18 years of age who developed stage 3 acute kidney injury (AKI) and underwent hemodialysis sessions during hospitalization were included. Stage 3 AKI was defined according to the Kidney Disease: Improving Global Outcomes (KDIGO) criteria [16] as: serum creatinine >4 mg/dL (or >3× baseline), anuria or urine output <0.3 mL/kg/h for 24 hours, or the need for renal replacement therapy (RRT). Patients underwent intermittent hemodialysis (IHD) sessions, with an average duration of 3–4 hours per session, typically one session per day.

The clinical variables collected included: gender, age, race/ethnicity, comorbidities, AKI etiology, reason for dialysis indication, number of IHD sessions, NTDLC insertion site, and hospital discharge outcome. Dialysis indications were based on the clinical evaluation performed by the hospital nephrology team. CRBSI was defined for patients who presented with a clinical picture compatible with bloodstream infection associated with a differential time to positivity between paired blood cultures from peripheral blood and catheter blood, with growth of the same microorganism in both cultures.

The microorganisms identified in blood cultures and their antimicrobial susceptibility profile (multisensitive vs. multidrug-resistant) were recorded. The hospital implements a catheter-related infection prevention bundle, which includes hand hygiene before catheter insertion and manipulation, use of maximal sterile barrier precautions, skin antisepsis with 0.5% alcoholic chlorhexidine, aseptic catheter insertion technique, disinfection of catheter connectors with 70% alcohol for 30 seconds before line manipulation, proper dressing care, and daily evaluation of catheter necessity. Patients under 18 years of age, with pre-existing chronic kidney disease, or with incomplete medical records were excluded.

2.2 Statistical Analysis

Data were analyzed using IBM SPSS Statistics v.29.0.0. Quantitative variables were described as means, standard deviations, minimum and maximum values, and categorical variables as absolute and relative frequencies. Associations between continuous variables were evaluated using the Student's t-test or ANOVA, and categorical variables were analyzed using Fisher's exact test or the chi-square test. Factors associated with the probability of CRBSI were assessed using logistic regression models, with the Wald test to evaluate variable significance. Associations were expressed as odds ratios (OR) with 95% confidence intervals (CI). A p-value <0.05 was considered statistically significant.

3. Results

Data from 290 patients with stage 3 AKI according to KDIGO who underwent hemodialysis during the study period were analyzed. The majority of patients were male (65.9%; n=191). Regarding race/ethnicity, 87.2% (n=253) self-identified as White, 10% (n=29) as Brown/mixed, and 2.8% (n=8) as Black. The mean age was 62.2 ± 2 years, with most patients in their seventh decade of life (26.9%, n=78). In this age group, the majority were female (61.5%, n=45). Among male patients, most were aged between 51 and 60 years (23.5%; n=45). Overall, 8% of patients were octogenarians or nonagenarians (Table 1).

Table 1. Age distribution of patients with AKI.

Age Group	n	%
< 20 years	17	5.8
21–30 years	11	3.8
31–40 years	18	6.2
41–50 years	30	10.3
51–60 years	56	19.3
61–70 years	78	26.9
71–80 years	57	19.7
> 81 years	23	8.0

Legend: AKI, Acute Kidney Injury.

Systemic arterial hypertension (SAH) and diabetes mellitus (DM) were the most prevalent comorbidities, affecting 49.3% (n=143) and 35.9% (n=103) of patients, respectively. Other reported comorbidities included dyslipidemia (10.3%, n=30), heart failure (12.4%, n=36), coronary artery disease (7.2%, n=21), hypothyroidism (8.6%, n=25), benign prostatic hyperplasia (5.5%, n=16), smoking (14.8%, n=43), and alcohol use (13.4%, n=39). The main etiology of AKI was sepsis (33.4%, n=97). Pulmonary sepsis was the leading source within the sepsis group (39.1% of sepsis patients, n=38), followed by abdominal focus (22.7%, n=22) and urinary focus (17.5%, n=17). Other AKI etiologies are shown in Table 2.

Table 2. Characteristics and outcomes of patients with AKI on dialysis by age group.

	Overall (n = 290)	Young ≤ 20 years (n = 17)	Adults 21–60 years (n = 115)	Elderly > 60 years (n = 158)
AKI Etiology, n (%*)				
Sepsis	97 (33.4)	10 (58.9)	30 (26.1)	57 (36.1)
Cardiorenal syndrome	46 (15.9)	1 (5.8)	13 (11.3)	32 (20.2)
Hypovolemia	30 (10.3)	0	14 (12.1)	16 (10.1)
Hepatorenal syndrome	13 (4.5)	0	4 (3.5)	9 (5.7)
Obstructive nephropathy	21 (7.3)	0	8 (7)	13 (8.2)
Glomerulonephritis	13 (4.5)	4 (23.5)	6 (5.2)	3 (1.9)
Burns	8 (2.7)	1 (5.8)	5 (4.3)	2 (1.3)
Rhabdomyolysis	21 (7.3)	1 (5.8)	16 (14)	4 (2.5)
Drug nephrotoxicity	29 (10)	0	15 (13)	14 (9)

	Overall (n = 290)	**Young ≤ 20 years (n = 17)**	**Adults 21–60 years (n = 115)**	**Elderly > 60 years (n = 158)**
Tumor lysis syndrome	12 (4.1)	0	4 (3.5)	8 (5)
Dialysis Indication, n (%*)				
Uremic syndrome	109 (37.6)	3 (17.6)	54 (47)	52 (33)
Refractory hyperkalemia	61 (21)	3 (17.6)	22 (19.1)	36 (22.7)
Refractory acidosis	49 (16.9)	2 (11.8)	17 (14.8)	30 (19)
Refractory hypervolemia	71 (24.5)	9 (53)	22 (19.1)	40 (25.3)
Dialysis Sessions				
Mean	4.9	5.3	5.3	4.4
Median	4	5	4	4
Min	1	1	1	1
Max	23	12	23	18
Outcomes, n (%*)				
Discharged recovered	81 (27.9)	10 (59)	36 (31.3)	35 (22.1)
Discharged on hemodialysis	51 (17.6)	1 (5.9)	31 (27)	24 (15.2)
Death	158 (54.5)	6 (35.1)	48 (41.7)	99 (62.7)

Legend: AKI, Acute Kidney Injury. %* = Percentage relative to the age group.

The main indication for initiating hemodialysis was symptoms related to uremic syndrome in 37.6% of patients, followed by refractory hypervolemia, hyperkalemia, and acidosis, accounting for 24.5%, 21%, and 16.9%, respectively. Patients underwent a mean of 4.9 ± 3.6 hemodialysis sessions per patient during hospitalization, with a minimum of 1 session and a maximum of 23 sessions (median 4 sessions).

The most frequently used insertion site for non-tunneled double-lumen catheters (NTDLC) was the right internal jugular vein (n=125, 43%), followed by the right femoral vein (n=110, 38%), left internal jugular vein (n=30, 10.4%), and left femoral vein (n=25, 8.6%). Catheter-related bloodstream infection (CRBSI) was observed in 14.5% of the sample (n=42). The most frequently isolated microorganism in blood cultures was Staphylococcus aureus (n=13, 30%), followed by Acinetobacter baumannii (n=4, 9.6%), Escherichia coli (n=4, 9.6%), and Staphylococcus epidermidis (n=4, 9.6%). The remaining isolated microorganisms and their antimicrobial resistance profiles are shown in Table 3. Among the 13 patients with Staphylococcus aureus infection, 7 were methicillin-sensitive and 6 were methicillin-resistant.

Table 3. Microorganisms isolated in CRBSI and antimicrobial susceptibility profile.

Isolated Microorganism	**n**	**%**
Staphylococcus aureus	13	30
Acinetobacter baumannii	4	9.6
Escherichia coli	4	9.6
Staphylococcus epidermidis	4	9.6
Candida albicans	3	7.2

Isolated Microorganism	**n**	**%**
Pseudomonas aeruginosa	2	4.8
Enterococcus faecalis	2	4.8
Staphylococcus haemolyticus	2	4.8
Klebsiella pneumoniae	2	4.8
Enterobacter cloacae	1	2.4
Haemophilus influenzae	1	2.4
Staphylococcus saprophyticus	1	2.4
Staphylococcus capitis	1	2.4
Streptococcus pneumoniae	1	2.4
Streptococcus bovis	1	2.4
Antimicrobial Susceptibility Profile	**n**	**%**
Multi-susceptible	26	62
Multi-resistant	16	38

Legend: CRBSI: catheter-related bloodstream infection.

No significant association was found between sex, age, or NTDLC insertion site and CRBSI; however, CRBSI was associated with a higher number of hemodialysis sessions per patient (OR 1.28 [1.17–1.41], p<0.001) (Table 4).

Table 4. Factors associated with CRBSI.

Variable	**n**	**CRBSI**	**p**	**OR (95% CI)**
		No	**Yes**	
Age (years), mean		63 ± 1.8	65 ± 1.6	0.735
Sex	Female	90 (90.9%)	9 (9.1%)	
	Male	158 (82.7%)	33 (17.3%)	0.065
Race	White	218 (86.2%)	35 (13.8%)	
	Brown/Black	30 (81.1%)	7 (18.9%)	0.414
Hemodialysis sessions per patient, mean		4 (1–18)	7 (1–23)	<0.001
NTDLC insertion site	Jugular veins	136 (87.7%)	19 (12.3%)	
	Femoral veins	112 (83.0%)	23 (17.0%)	0.251

Legend: CRBSI. Catheter-related bloodstream infection. HD. Hemodialysis. NTDLC. non-tunneled double-lumen catheter.

Overall mortality was 54.5% (n=158), with the majority being male patients (64.5%, n=102). Approximately 18% of patients were discharged depending on renal replacement therapy. Mortality was significantly higher in elderly patients (>61 years) compared to those ≤60 years (p<0.001); however, there was no statistically significant difference in renal function recovery between young patients (<20 years) and elderly patients (>60 years) (p=0.08).

4. Discussion

According to epidemiological data from Brazil, analyzed in a study conducted between 2014 and 2019, acute kidney injury (AKI) was more prevalent in men (56.7%), self-declared white individuals (36.2%), and in the age group of 60–69 years (22.2%) [17], which is consistent with the findings of this study. Data regarding race/ethnicity are similar to studies considering national data, where most of the population is self-declared white. However, some regional studies may differ according to the local population, such as in the state of Bahia, where an epidemiological study reported that 81% of patients self-identified as brown [18].

The high prevalence of elderly patients in our sample is noteworthy. Reports indicate up to an 8-fold increase in the prevalence of AKI in patients over 60 years of age [19]. Recent studies conducted in Brazil show rising numbers of AKI in older patients, associated with higher mortality rates [20, 21], reaching 66.7% in nonagenarian patients who develop AKI [21]. It is important to highlight that advanced age is not only a risk factor for AKI but also for mortality and permanent loss of renal function [22].

Studies show that conditions leading to renal hypoperfusion and ischemia are directly associated with the development of AKI, and a reduction in renal functional reserve allows the onset of this injury even with minor renal insults [23]. Advanced age, diabetes mellitus (DM), systemic arterial hypertension (SAH), and cardiovascular diseases (e.g., heart failure, coronary artery disease, peripheral vascular disease) are comorbidities frequently associated with a higher risk of developing AKI [17]. Patients in this study presented clinical characteristics and etiologies for AKI similar to those reported in the literature. AKI in the context of sepsis is one of the main etiologies, and mortality rates are high, around 50–60% of cases [20, 22–26]. With improvements in techniques and greater access to renal replacement therapies, deaths directly related to renal injury have decreased; however, mortality among patients requiring acute dialysis therapy remains high, and patients are exposed to complications inherent to the dialysis procedure itself, including death [22, 25].

In addition to mortality associated with acute kidney injury and the dialysis procedure, catheter-related bloodstream infection (CRBSI) contributes to patient outcomes [12]. The incidence of CRBSI varies between studies; however, it is noticeable that longer catheter dwell time is directly related to higher CRBSI rates [10, 27]. Although the present study did not specifically analyze catheter dwell time, there was an association between the number of intermittent hemodialysis (IHD) sessions and CRBSI incidence. It can be inferred that patients who underwent more sessions remained longer with non-tunneled double-lumen catheters (NTDLC) and were exposed to greater catheter manipulation during dialysis, contributing to higher infection rates. Although not the majority of isolated microorganisms, the prevalence of multi-drug resistant (MDR) pathogens is noteworthy. AKI patients are often treated in intensive care units (ICUs), where MDR organisms are prevalent due to prolonged antibiotic use, multiple invasive devices, and patient severity, as well as higher MDR prevalence in burn units [28, 29].

This study has limitations. Being based on electronic medical record data, it is subject to missing data and collection errors. An important limitation is the lack of information regarding catheter dwell time. This information was not available in all records, preventing the use of the standard metric to report CRBSI incidence in "episodes per 1,000 catheter-days." We also considered as a limitation the lack of distinction between patients in ICU and general wards (areas with patients of differing severity), since many patients were hospitalized in both locations during the same admission, often with the same NTDLC. Nevertheless, it is important to understand the patient profile and outcomes to identify high-risk patients early and implement local preventive measures to reduce adverse events.

5. Conclusion

In conclusion, dialysis-requiring AKI can affect patients of all ages, notably elderly patients over 60 years. Infectious conditions are often the cause of AKI, such as AKI in the context of sepsis, but infections can also be related to its management, such as CRBSI. Mortality among AKI patients is high. CRBSI is more common in patients with NTDLC requiring more IHD sessions and greater device manipulation, and there is a considerable proportion of CRBSI caused by MDR pathogens. Studying local epidemiology is essential to guide and implement preventive measures.

Funding: This study was approved by the Research Ethics Committee of Faculdade Evangélica Mackenzie do Paraná (CAAE 83654024.8.0000.0103) in October 2024.

Research Ethics Committee Approval: None.

Acknowledgments: None.

Conflicts of Interest: The authors declare no conflict of interest.

Supplementary Materials: None.

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