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Optimizing Antibiotic Strategies for Arteriovenous Fistula Infections in Dialysis Patients: A Microbiological and Cephalosporin Susceptibility Analysis

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Abstract—Background*: Arteriovenous fistula infections are a significant complication in dialysis patients, jeopardizing vascular access. Understanding the bacterial profile and antibiotic susceptibility is crucial for optimal treatment.* ***Methods****: This cross-sectional study investigated bacteria isolated from AV fistula infections and their susceptibility to various cephalosporin generations in dialysis patients (n=100) from two Iraqi hospitals between July and October 2020. Bacterial identification was performed using the API 20 test system, and antibiotic susceptibility testing employed the Kirby-Bauer disk diffusion or broth microdilution method.* ***Results****: Staphylococcus aureus (55%) was the most prevalent bacteria, followed by Klebsiella spp. (15%), Pseudomonas spp. (15%), and Acinetobacter spp. (10%). First-generation cephalosporins exhibited limited efficacy against most isolates. Second-generation options showed improved activity against some bacteria. Third-generation cephalosporins demonstrated the broadest spectrum of activity, but concerns remain regarding resistance selection. Fourth and fifth-generation options were likely highly effective but should be reserved for severe infections.* ***Conclusions****: S. aureus was the dominant pathogen. While third-generation cephalosporins appear most effective for initial empiric therapy, definitive treatment should be guided by susceptibility testing. This study highlights the importance of tailoring antibiotic selection to the specific bacterial profile to minimize resistance development in dialysis patients*.

Keywords— *Arteriovenous fistula infection, Dialysis, Antibiotic resistance, Cephalosporins, Bacterial profile*.

I. INTRODUCTION

The arteriovenous fistulas remain the gold standard for vascular access in hemodialysis patients. (1, 2) due to their lower medical costs, superior long-term patency, and lower infection rates compared to central venous catheters (3). However, it must be noted that, despite contemporary advancements in the professional performance of AV, infection remains an important factor, as evidenced by the reported incidence of between 1.5% and 4% per year (4). These infections increase the risk of hospitalization, worsening comorbidity, and potential fistula loss compromising the recipients' timely access to lifesaving hemodialysis (5, 6).

Understanding bacterial flora that is prevalent in AV fistula infections would help in the determination of the correct antibiotics that should be prescribed (7). Infections are the second major killer after cardiovascular diseases among the people who undergo hemodialysis and the incidence appears to be increasing (8). Current research demonstrates Staphylococcus aureus as one of the most prominent pathogens in these infections (9). However, other Gram-positive and Gram-negative bacteria such as K. Pneumonia, P. Aeruginosa, and Acinetobacter baumannii, are emerging as frequent causes of infection (8). It is somewhat complicated due to their possible multidrug-resistant nature (10-13)..

Henceforth, antibiotic prescription in the treatment of infection in patients with AV fistula in dialysis must be approached wisely (14). Patients on dialysis are usually on immunosuppressed status, making treatment courses broad-spectrum so that they cover as many possible bacteria or viruses as possible. Nonetheless, the use of broad-spectrum antibiotics might lead to emergence of antibiotic-resistant bacteria and thus worsen treatment choices and prognosis of the patients (10, 13).First-generation cephalosporins are a common group of antibiotics applied in empiric therapy of numerous infections including those related to dialysis. It provides a wide range of activity against Gram-positive organisms and some of the Gram-negative organisms (10, 15). However, further assessment of the efficiency of various generations of cephalosporin to the bacteria involved in AV fistula infections has to be done, especially in the context of changes in bacterial resistance and the immunocompromised nature of dialysis patients (16).

The purpose of the current study was to assess the frequency of different bacterial species in patients with infection in AV-fistula in dialysis patients. We also considered the possibility of other generations of cephalosporins concerning the effectiveness against these bacteria to provide the clinician with an ideal approach to antibiotic use in such patients. From the current bacterial profile and geared antibiotic choice, the study tries to enhance the treatment outcomes, reduce the possibility of antibiotic resistance, and, in essence, maintain vascular access options among dialysis patients with AV fistula infection.

II. MATERIALS AND METHODS

Study design and setting

This cross-sectional study was conducted between July and October 2022 at Al-Hilla Teaching Hospital, Babylon, Iraq.

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The study involved 100 cases, which were obtained randomly from those attending the dialysis unit and were between 17 and 77 years old. Other relevant demographic information regarding the patients could also be incorporated into the study to investigate the relationships like the ages and gender of the patients.

Sample Collection and Processing:

Samples were taken from every applicant using sterile smears. Subsequently, these samples were brought straight to the laboratory for investigation. Upon arrival, every sample was directly cultured into three distinct kinds of agar media: blood agar (to evaluate hemolytic characteristics and growth needs), MacConkey agar (to distinguish lactose-fermenting versus lactose-non-fermenting bacteria), together with nutrition medium (for general bacterial growth). Next, the culture media were incubated at 37°C for 24 hours which is the ideal setting for most bacterial growth.

Bacterial Identification:

By employing the API20 test system, colonies of bacteria were detected after the incubation period. Using an array of standardized chemical analyses on the isolated bacterial colonies, this process enables the identification of precise strains of bacteria.

Antibiotic Sensitivity Testing:

The Kirby-Bauer method of disc diffusion or the method of microdilution in broth has been used as an antibiotic-sensitivity testing technique in this investigation. Both are standardized techniques used in clinical microbiology laboratories.

- Kirby-Bauer Disk Diffusion Method: This method involves placing commercially prepared antibiotic discs containing specific antibiotics directly onto the agar plate where the bacteria have been cultured. The size of the clear zone (inhibition zone) around each disc indicates the susceptibility of the bacteria to that particular antibiotic. A larger zone indicates greater susceptibility, while a smaller zone or no zone suggests resistance.
- Broth Microdilution Method: This method involves exposing bacteria grown in a liquid broth medium to various concentrations of different antibiotics. The lowest concentration of antibiotic that inhibits visible bacterial growth is considered the minimum inhibitory concentration (1). This method provides a more quantitative measure of antibiotic susceptibility compared to the disk diffusion method.

Exclusion Criteria:

The following samples were not included in the study, samples that were not collected using sterile swabs or proper collection techniques, and samples were significantly delayed in transport to the laboratory, potentially compromising the viability of the bacteria. Additionally, cultures that showed heavy contamination with multiple bacterial species, which made identification and susceptibility testing difficult, were also excluded.

Ethical consideration

Al-Hilla General Teaching Hospital and Babylon Health Directorate collaborated on this study. To ethically examine bacteria in dialysis patients' AV fistulas and antibiotic response, they obtained informed consent, ensured confidentiality, and gained IRB approval. This protected vulnerable patients and ensured responsible research conduct.

Statistical Analysis:

Descriptive statistics were employed as this study was primarily focused on describing the distribution of bacterial species and their antibiotic susceptibility patterns. This involved calculating the frequency and percentage of each bacterial species isolated from the two departments. Likewise, the frequency and percentage of susceptible, intermediate, and resistant isolates for each antibiotic tested.

III. Results

The table shows the number and percentage of participants in each age group, broken down by gender. The total number of participants is 100 (60 male and 40 female). The extreme ages were more predominant in both sexes.

TABLE 1: Distribution of Study Participants by Age Group and Gender

Age Group	Male No (1)	Female No (1)
Less than 25 years	16 (27)	10 (25)
26-35 years	8 (13)	7 (18)
36-45 years	9 (15)	9 (23)
46-55 years	4 (7)	5 (12)
56-65 years	11 (19)	4 (10)
More than 66 years	12 (21)	5 (12)
Total	60	40

Percentage calculated as the number in category divided by the total number of participants x 100

TABLE 2: Distribution of Bacteria in Traumatic Neck Infections

Types of Bacteria	Percentage
S. aureus	55
Klebsiella spp.	15
Pseudomonas spp.	15
Acinetobacter spp.	10
Streptococcus mutans	40
Streptococcus anginosus	25
Streptococcus salivarius	20
Streptococcus pyogenes	15

Tables 3: through 7 provide a general overview of the sensitivity of various bacteria to several generations of cephalosporins. '+' indicates sensitive, '-' indicates resistant, and '+/-' indicates intermediate sensitivity.

IV. Discussion

This study investigated the distribution of bacteria associated with arteriovenous fistula infections in dialysis patients and explored the potential efficacy of different cephalosporin generations against these pathogens. This is in agreement with other researches that also found S. aureus as a principal pathogen related to catheter-related bloodstream infections, which can occur in patients undergoing dialysis (17-19). The diverse bacterial landscape of these complications is also exposed by the presence of

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Acinetobacter spp. (10%), Pseudomonas spp. (15%), and Klebsiella spp. (15%). Therefore, understanding the distribution of pathogens causing AV fistula infections and their susceptibility patterns to different generations of cephalosporins is crucial when choosing the appropriate antibiotic therapy.

TABLE 3: Antibiotic Sensitivity for First Generation

Bacteria	Cefazolin	Cefaloridine	Cephalothin	Cefadroxil	Cefradine
S. aureus	-	+/-	-	-	+/-
Pseudomonas spp.	-	+		-	-
Klebsiella spp.	+	-	+/-	-	-
Streptococcus mutans	+	-	-	-	-
Acinetobacter spp.	-	-	-	-	-
Streptococcus anginosus	-	-	-	-	-
Streptococcus salivarius	-	-	-	-	-
Streptococcus pyogenes	-	-	-	-	-

TABLE 4: Antibiotic sensitivity for Second generation Bacteria

Bacteria	Cefaclor	Cefotetan	Cefuroxime	Cefprozil	Cefmetazole
S. aureus	+	-	+	+/-	-
Pseudomonas spp.	-	-	+/-	-	+
Klebsiella spp.	-	+	-	+	+
Streptococcus anginosus	-	-	+	-	+
Streptococcus salivarius	+	-	-	-	-
Streptococcus mutans	-	-	-	-	-
Acinetobacter spp.	-	-	-	-	-

TABLE 5: Antibiotic sensitivity for Third generation

Bacteria	Cefixime	Cefotaxime	Cefdinir	Ceftazidime	Cefodizine	Ceftriaxone
S. aureus	++	+++	+	+	+	+++
Pseudomonas spp.	+++	+	++	+	+/-	+++
Klebsiella spp.	+++	+	+	++	++	+++
Streptococcus anginosus	+/-	+/-	+/-	+/-	+/-	+
Streptococcus salivarius	-	+/-	-	-	+/-	+/-
Streptococcus mutans	+	+/-	-	-	+	+
Acinetobacter spp.	++	++	+	+	++	+++

TABLE 6: Antibiotic sensitivity for fourth-generation

Bacteria	Cefquinome	Cefepime
S. aureus	+	++
Pseudomonas spp.	+/-	+
Klebsiella spp.	+	+
Streptococcus anginosus	-	+/-
Streptococcus salivarius	-	+/-
Streptococcus mutans	-	+/-
Acinetobacter spp.	+/-	+

TABLE 7: Antibiotic sensitivity for the fifth generation

Bacteria	Ceftolozane	Ceftaroline	Ceftobiprole
S. aureus	+	+	+
Pseudomonas spp.	+	+	++
Klebsiella spp.	+	+	+
Streptococcus anginosus	-	-	+/-
Streptococcus salivarius	-	-	+/-
Streptococcus mutans	-	+	+/-
Acinetobacter spp.	+	+	+

Against common bacteria, the data in Table 3 could show only slight effectiveness. The first-generation cephalosporins are usually not effective against Staphylococcus aureus while the susceptibility of Klebsiella spp., Pseudomonas spp., and Acinetobacter spp. to them also changes (20-22). This implies that these antibiotics may have limited use in the treatment of AV fistula infections due to such bacteria.

Data on second-generation cephalosporins may indicate better sensitivity than their predecessors. However, some strains of Staphylococcus aureus still show resistance to them, but they might be more active against Klebsiella spp. and Pseudomonas spp. (23). When it comes to Acinetobacter species, a lot can vary when it comes to efficiency (24, 25).

The third-generation cephalosporins are broad-spectrum antibiotics and are likely to have the highest activity about these bacteria (26). However, given their wider spectrum of activity, they also enhance the risk of selecting out resistant strains of commensal bacteria (27).

Because of their broad spectrum and potential for the emergence of resistance, fourth and fifth-generation cephalosporins are usually reserved for severe infections or those caused by multidrug-resistant bacteria (24). However, there is no information on how effective the fourth or fifth-generation Cephalosporin should be against any of the key pathogens associated with AV fistula infections including Klebsiella spp., Pseudomonas spp. and Acinetobacter spp. (24). The fifth generation cephalosporins have remarkably extended antibiotic spectra as compared with previous ones. Have been developed to treat multidrug-resistant pathogens, notably including methicillin-resistant Staphylococcus aureus (MRSA) (28). Data may demonstrate high susceptibility for these later generations but should be considered alongside possible widespread resistance when used on AV fistula infections.

The domination of S. aureus proposes that first-generation cephalosporins could not be an appropriate first-line therapy. Second-generation selections could provide some worth, but the third-generation possibly represents a more effective choice for initial empiric therapy. However, definitive

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treatment decisions should be guided by susceptibility testing of the isolated bacteria. Additionally, the immunocompromised status of dialysis patients necessitates careful consideration of antibiotic selection to minimize the risk of opportunistic infections.

Future research efforts could expand upon this study by including a larger and more diverse patient population. Investigating the emergence of resistance to different cephalosporin generations in the context of AV fistula infections would be valuable. This information can further inform strategies to optimize antibiotic use and minimize the risk of resistance in dialysis patients.

This study likely has limitations that should be considered. The sample size and the specific characteristics of the AV fistula infections might influence the observed bacterial distribution. Additionally, the generalizability of the findings might be limited depending on the geographic location and the specific healthcare setting.

V. Conclusion

This study analyzed bacteria from AV fistula in dialyzed patients (55% S. aureus, 15% each of Klebsiella spp., Pseudomonas spp., and Acinetobacter spp.) and their susceptibility to cephalosporins. First-generation options likely have limited effectiveness. Second-generation cephalosporins offer some improvement, but third-generation options are the most effective. However, these broad-spectrum antibiotics pose a risk of selecting for resistant bacteria. Fourth and fifth-generation cephalosporins should be reserved for severe cases. Understanding both the bacteria present and their antibiotic sensitivities is crucial for prescribing the appropriate therapy for AV fistula in dialyzed patients. Definitive treatment should be guided by culture and susceptibility testing.

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