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The growing concern of MDR/XDR bacteria in patients undergoing dialysis: a cross-sectional study

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Abstract. ***Background.*** *Dialysis patients are at heightened risk for multidrug-resistant (MDR) and extensively drug-resistant (XDR) bacterial infections due to their vulnerability to infections and frequent exposure to healthcare environments. This study aims to determine the prevalence, risk factors, and antimicrobial resistance patterns of these pathogens to enhance patient care and infection control strategies.* ***Materials and methods.*** *This cross-sectional study was conducted at the Al-Hussein Teaching Hospital Dialysis Unit in Thi-Qar, Nasiriyah, Iraq, from September to December 2024, involving 121 dialysis patients. Data collected from participants included demographic information, comorbidities, and dialysis-related parameters. Microbiological analysis involved urine sample processing through bacterial culture, with bacterial identification and antimicrobial susceptibility testing performed using the VITEK 2 Compact system.* ***Results.*** *The mean age of the study population was 55.0 ± 16.6 years, with a higher proportion of males (52.9 %). Diabetes mellitus was the most common comorbidity, affecting 70 % of patients either alone or in combination with hypertension and cardiovascular disease. The culture positivity rate was 19.0 %, with E.coli being the most frequently isolated pathogen (65.2 %), followed by K.pneumoniae (21.7 %) and E.cloacae (13.1 %). Antimicrobial resistance testing revealed that 60 % of E.coli and all K.pneumoniae isolates were MDR, while 40 % of E.coli and 33.3 % of E.cloacae were XDR. A significant negative correlation was observed between dialysis duration and infection frequency (r = –0.2285, p = 0.0117), indicating a higher likelihood of infections during the initial year of dialysis therapy.* ***Conclusions.*** *The findings underscore the high prevalence of MDR/XDR bacterial infections among dialysis patients, particularly during the early stages of treatment. This highlights the urgent need for enhanced infection control measures, robust antimicrobial stewardship programs, and regular surveillance within dialysis facilities. Targeted interventions are essential to reduce infection-related morbidity and mortality among this vulnerable patient population.*

Keywords: *MDR; XDR; dialysis patients; chronic kidney disease*

Introduction

Chronic kidney disease (CKD) is one of the leading global challenges today, with increasing incidence of the disease due to rising prevalence of diabetes, hypertension and increasing life expectancy [1]. CKD is defined by the slow deterioration of the kidney function and can eventually result in end-stage renal disease (ESRD) where patient must undergo either dialysis or kidney transplantation. Patient with CKD especially those on dialysis are at high risk of infections because of their impaired immune system, frequent hospital visits and the use of devices such as central venous catheter and arteriovenous fistula [2, 3].

MDR and XDR bacterial infections are a major problem in dialysis patients worldwide. These infections lead to higher rate of mortality, mortality, length of hospital stay and cost of health care [4–6]. This is because patients on dialysis are more likely to visit hospitals frequently, have weakened immune system and be exposed to more invasive procedures which make them have a high chance of having antibiotic resistant pathogens WHO and CDC have classified MDR/XDR bacteria as emerging threats to public health and called for immediate surveillance and control measures to contain their spread [7, 8].

Current evidence highlights the growing issue of multidrug resistance in dialysis-associated infections. A retrospective cohort study based on 1155 episodes of peritoneal dialysis associated peritonitis (PDAP) showed that 12.6 %

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of the episodes were caused by multi-drug-resistant organisms. This article also established that prolonged dialysis and history of PDAP were the factors that were associated with worse outcomes and therefore suggested individualized and expedite management of the condition [9]. In addition, a cross-sectional study conducted among haemodialysis patients in Palestine investigated the resistance patterns of the pathogens and found high frequency of resistance to methicillin resistant *Staphylococcus aureus*, *Escherichia coli* carrying extended spectrum beta lactases and *Stenotrophomonas maltophilia* and thus accentuated the necessity of the appropriate empirical coverage based on the susceptibility patterns [10].

These studies, therefore, emphasis the necessity of surveillance, specific antibiotic use, and active infection control measures to combat the effects of MDR/XDR bacterial infections among dialysis care. However, there is limited information on MDR/XDR bacterial infections in dialysis patients around the world, including the Middle East such as Iraq. With the growing incidence of CKD and the use of dialysis in this region, there is a need to conduct region-based studies to determine the prevalence of resistance patterns, risks and outcomes. Hence, the cross-sectional study was conducted to comprehensively assess the prevalence and features of MDR and XDR bacterial infections among patients on dialysis in a large urban healthcare system, with the view of providing important information that may help in the formulation of effective interventions to combat these resistant bacteria in this high-risk group of patients.

The purpose. To determine the prevalence, risk factors, and antimicrobial resistance patterns of these pathogens to enhance patient care and infection control strategies.

Materials and methods

Study design and population

This cross-sectional study was carried out at the Al-Hussein Teaching Hospital Dialysis Unit in Thi-Qar/Nasiriyah City, Iraq, which is a referral health facility that receives patients of all ages. Thi-Qar is a Governorate located in the southern part of Iraq and has an estimated population of over 2 million. The Dialysis Unit offers both inpatient and outpatient dialysis services to meet the various needs of the patients. 121 patients who were on haemodialysis at the unit during the period September-December 2024 were involved in the study.

Data collection

With a thorough extraction process, the hospital's electronic medical records provided comprehensive clinical and demographic data. The collected data spanned across multiple areas including age, gender, comorbidities (diabetes, hypertension, cardiovascular disease), dialysis modality and duration, dialysis session frequency and current symptoms. A meticulous data collection process was established to ensure that it covered the entire patient population which was crucial for subsequent analysis.

Microbiological analyses

Urine samples from all study participants were used to determine the prevalence as well as characteristics of MDR and XDR bacterial infections. In line with the study's objectives, all participants' urine samples were processed at the hospital's microbiology laboratory following the guidelines of the Clinical and Laboratory Standards Institute (CLSI). The urine samples were cultured on different type of culture medias such as Blood agar, MacConkey agar, and Mannitol Salt agar to isolate bacteria. Biochemical testing, Gram staining and colony morphology were used for initial bacterial identification. The VITEK 2 Compact system (bioMérieux, Marcy-I'Étoile, France) was used to perform AST for all bacterial isolates. Antibiotic susceptibility over a broad spectrum of antibiotics was determined. The susceptibility, multidrug resistance (MDR), and extensive drug resistance (XDR) categories were defined by CLSI and EUCAST guidelines.

Statistical analysis

All data analyses were carried out using GraphPad Prism (version 10). Patient characteristics and bacterial resistance data were expressed through descriptive statistics, including mean, median, and standard deviation. The association between clinical variables and MDR/XDR bacterial infections was evaluated using univariate analysis, including the chi-square test, and Fisher's exact test. Multivariate logistic regression was applied to determine the independent risk factors while controlling for potential confounders like age, dialysis duration, and comorbidities. A p-value < 0.05 was set as the threshold for statistical significance.

Ethical considerations

The study protocol was approved by Institutional Review Board (IRB) of Al-Hussein Teaching Hospital with the approval number [252/2024]. The ethical guidelines such as the Declaration of Helsinki were adhered to in order to protect the patient's confidentiality and data protection. All participants or their legal guardians signed a written informed consent form before including them in the study.

Results

Patient demographics and age distribution

Analysis of the age distribution among dialysis patients revealed distinct patterns within the study cohort. The highest frequency was observed in the 61–70 age group, comprising 35 patients, representing nearly one-third of the total population (Fig. 1A). The mean age of the study population was 55.0 ± 16.6 years, with a median age of 58.0 years. The slight left skew in the age distribution suggests a greater presence of younger outliers, including paediatric and young adult patients. The unimodal distribution pattern showed a gradual increase in patient frequency, peaking in the middle-age range, followed by a decline in elderly patients. The demographic data also showed sparse representation across both the 0–30 and 80+ years categories. The smooth kernel density estimation (KDE) curve mirrored the histogram bars, again showing a single mode in the distribution and rather nicely capturing the age trends within the dialysis population. Gender distribution showed approximately equal numbers of patients with 64 males (52.9 %) and 57 females (47.1 %). The results of descriptive statistics revealed

that the male patients were 56.0 ± 15.1 years of age, with a median of 59.0 years while female patients were somewhat younger with a mean age of 53.9 ± 18.3 years, a median of 57.0 years. The cumulative age distribution analysis revealed that female patients exhibited a wider age range compared to males, as evidenced by the broader interquartile range (Fig. 1B). Despite these variations, the cumulative distribution curves showed substantial overlap between genders, indicating similar overall age structures within the dialysis patient population.

Comorbidities and symptoms in dialysis patients

The prevalence of comorbidities among dialysis patients demonstrated a complex distribution of concurrent medical conditions (Fig. 2A). Diabetes mellitus (DM) was the most common single comorbidity, affecting 28 patients (24.6 %), followed closely by the combination of diabetes mellitus and hypertension (DM + HTN) in 27 patients (23.7 %). A notable subset of 25 patients (21.9 %) had a triple combination of DM, HTN, and cardiovascular disease (CVD), highlighting the burden of multiple comorbidities. Additionally, 23 patients (20.2 %) had only hypertension, while 11 patients (9.6 %) had CVD alone. Overall, 70 % of the patients had diabetes, either alone or in combination with other conditions, underscoring its dominant role in the comorbidity profile.

The symptoms reported by patients were diverse (Fig. 2B). The most common presentation was a combination of symptoms described as multiple (34 patients), followed by fever, reported by 20 patients. Single symptoms such as flank pain and dysuria were observed in 13 and 12 patients, respectively, while specific combinations like dysuria with flank pain were noted in 7 patients. This detailed arrangement, ordered by frequency, provides a clear picture of the relative prevalence and potential clinical significance of each symptom profile. The box plot analysis revealed that patients with more complex comorbidity profiles tended to have a longer duration on dialysis compared to those with a single condition (Fig. 2C). This suggests a potential cumulative impact of multiple chronic conditions on the progression of renal failure and the need for prolonged dialysis therapy.

The analysis of dialysis duration across different symptom groups revealed considerable variability (Fig. 2D). Patients presenting with dysuria and fever had the longest median dialysis duration (46.0 months), followed by oedema (38.0 months) and dysuria alone (37.5 months). In contrast, patients experiencing flank pain had the shortest median duration (20.0 months). The largest subgroup, which consisted of 34 patients with multiple symptoms, had a moderate median of 26.5 months. The Kruskal-Wallis test did not show any statistically important differences between symptom groups ($p = 0.799$) which means that, differences in dialysis duration were more likely to be attributed to patient factors rather than to symptom profiles. These findings point to the complex relationship between the presence of comorbidities and dialysis related symptoms, thus stressing the importance of individualized approaches for dialysis patients' management. Statistical analyses presented here reveal a strong association between the burden of comorbidities, the nature of current symptoms and the duration of dialysis. The results of this study suggest that patients with multiple comorbidities and certain symptoms are likely to be on dialysis for a longer period, which opens further research on multivariate analysis to understand the determinants of the pathways and to develop specific interventions in clinical practice.

Dialysis treatment patterns and duration analysis

Analysis of dialysis frequency showed that most patients (67.8 %) underwent dialysis three times per week, while 32.2 % received dialysis twice weekly (Fig. 3A). The median dialysis duration was 30 months for the thrice-weekly group and 25 months for the twice-weekly group. Although the Kruskal-Wallis test yielded a p-value of 0.799, indicating no statistically significant difference in dialysis duration between frequency groups, individual variability was notable (Fig. 3B). These findings emphasize the predominance of thrice-weekly dialysis regimens, and the importance of individualized treatment approaches that account for patient-specific factors beyond just dialysis frequency.

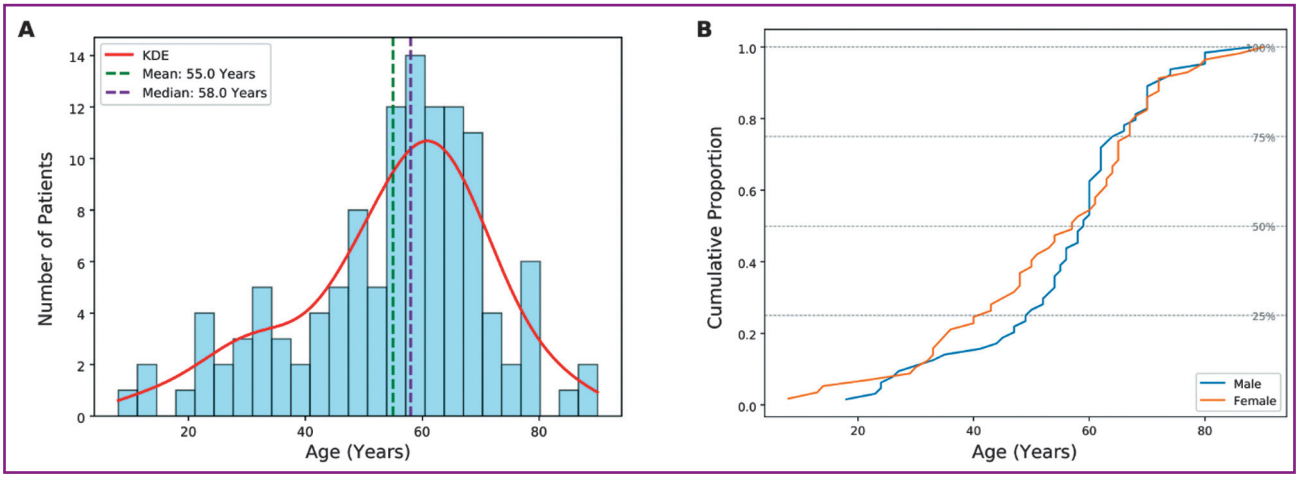

Figure 1. The age distribution of dialysis patients. A. The histogram and kernel density plot depict a unimodal age distribution, with a distinct peak in the 61–70 age group. B. The cumulative distribution curves illustrate the age patterns of dialysis patients by gender, indicating substantial overlap between males and females

Prevalence of bacterial infections and associated clinical outcomes

Of the 121 patients analysed, 23 (19.0 %) had culture-positive results, while 98 (81.0 %) had negative cultures. Patients with positive cultures had a slightly older mean age (57.61 ± 16.71 years, median 60 years, range 24–86 years) compared to those with negative cultures (54.39 ± 16.64 years, median 58 years, range 8–90 years), but the Mann-Whitney U test revealed no statistically significant difference in age distribution (p = 0.4632) (Fig. 4A).

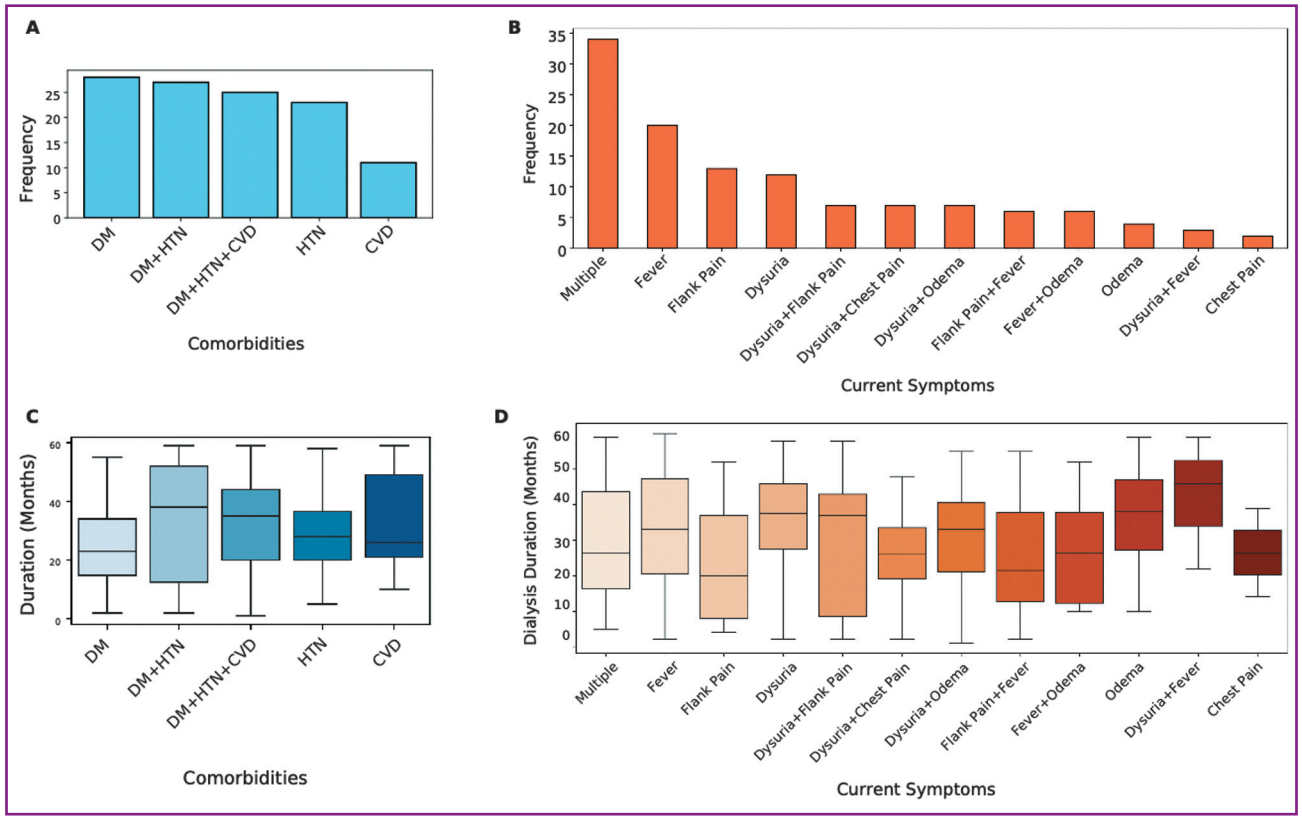

Figure 2. Comorbidities and symptomatology in dialysis patients. A. The distribution of comorbidities among patients presents the prevalence of diabetes mellitus, hypertension, and cardiovascular disease, either alone or in combination. B. The frequency of various symptom profiles observed in dialysis patients, ordered by decreasing prevalence. C. The boxplots illustrate the relationship between comorbidity complexity and dialysis duration, indicating longer dialysis duration for patients with multiple comorbidities. D. The variability in dialysis duration across different symptom groups, with dysuria and fever presenting the longest median duration

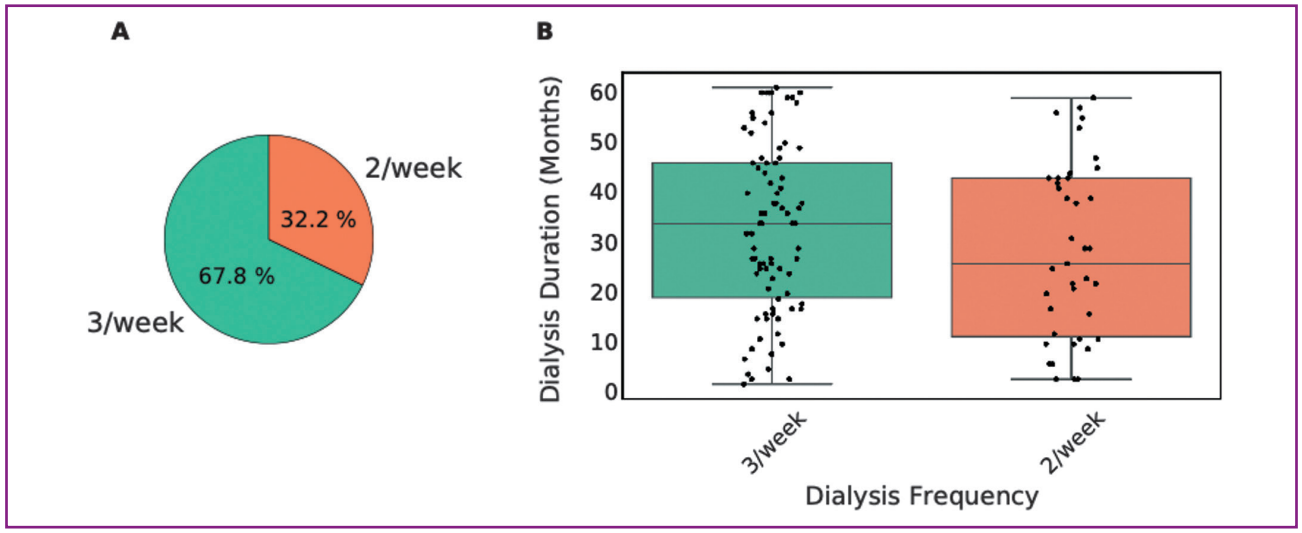

Figure 3. Dialysis treatment patterns and duration. A. The distribution of dialysis frequency, showing that 67.8 % of patients received dialysis three times per week, while 32.2 % were treated twice weekly. B. The boxplots illustrate the median dialysis duration for the two dialysis frequency groups, with the thrice-weekly group having a slightly longer median duration, although the difference was not statistically significant

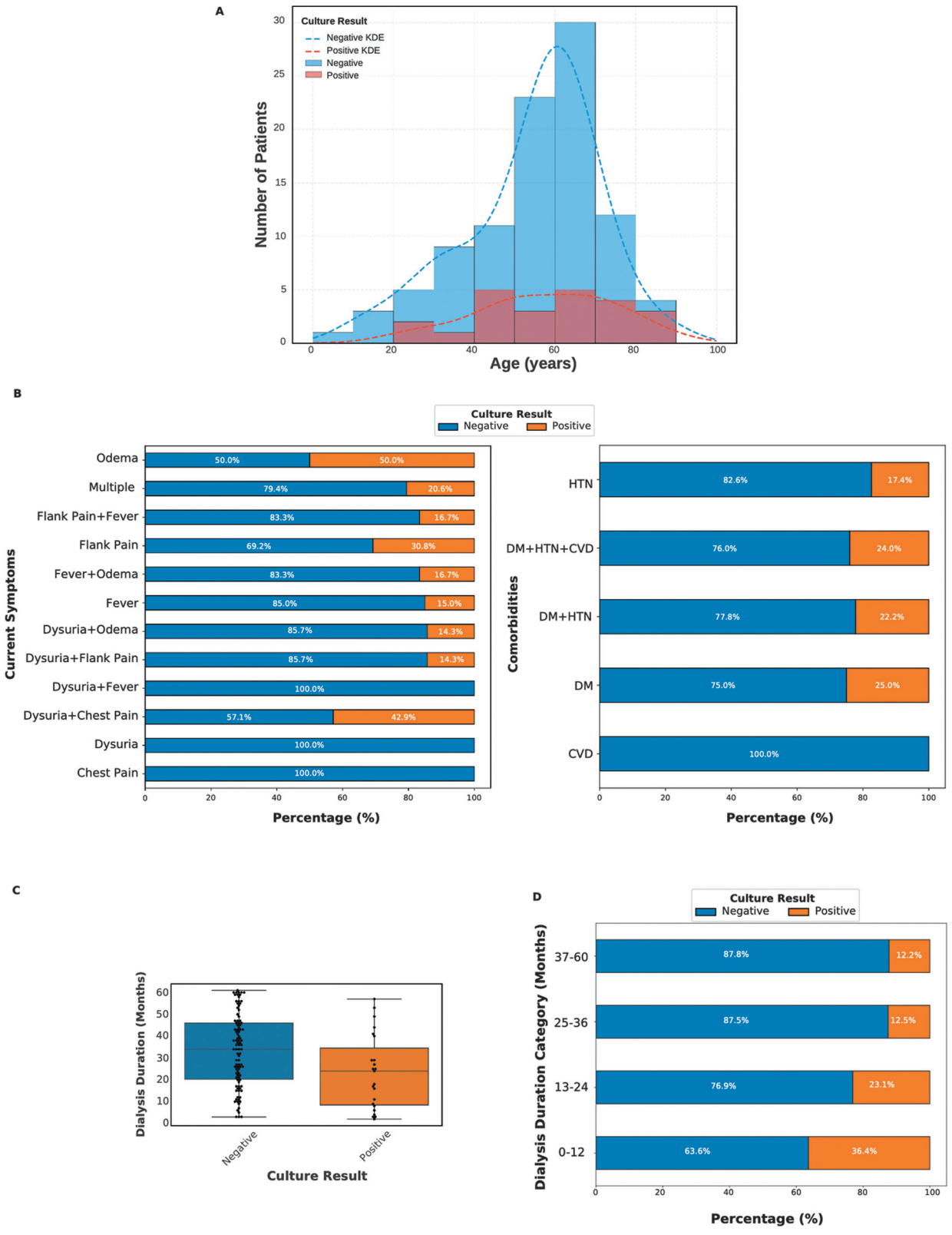

Figure 4. Prevalence of bacterial infections and associated outcomes. A. The distribution of culture-positive, culture-negative results and ages among dialysis patients. B. The prevalence of positive cultures across different symptom profiles and comorbidities. C. The boxplot comparing the dialysis duration between culture-positive and culture-negative groups, showing significantly shorter duration in the positive group. D. The trend in culture positivity rates over the duration of dialysis categories, with the highest rate observed in the first year and a steady decline thereafter

Analysis of culture outcomes by symptom category revealed that patients with flank pain, dysuria plus chest pain, and oedema had the highest rates of positive cultures (30.8–50.0 %), whereas those with dysuria plus flank pain and dysuria plus oedema had the lowest rates (14.3 %) (Fig. 4B). Comorbidity analysis showed that patients with diabetes had the highest rate of positive cultures (25 %), followed by those with DM + HTN + CVD (24 %). No positive cultures were observed in patients with only CVD (Fig. 4B).

Further analysis showed that dialysis duration significantly differed between culture-positive and culture-negative patients (Fig. 4C). The negative culture group had a longer mean dialysis duration (32.4 ± 16.6 months, median 33.0 months) compared to the positive culture group (22.5 ± 17.1 months, median 23.0 months). This difference was statistically significant (Mann-Whitney U = 1497.0, p = 0.0146), suggesting a protective effect of longer dialysis duration against positive cultures. A significant negative correlation (r = –0.2285, p = 0.0117) was observed between dialysis duration and culture positivity, reinforcing this association. The highest proportion of positive cultures was seen in patients within their first year of dialysis (34.78 %), with a steady decline in subsequent years (Fig. 4D). The lowest rate (8.70 %) was recorded among patients who had been on dialysis for 49–60 months. These findings suggest that the first year of dialysis represents a high-risk period for bacterial infections, warranting

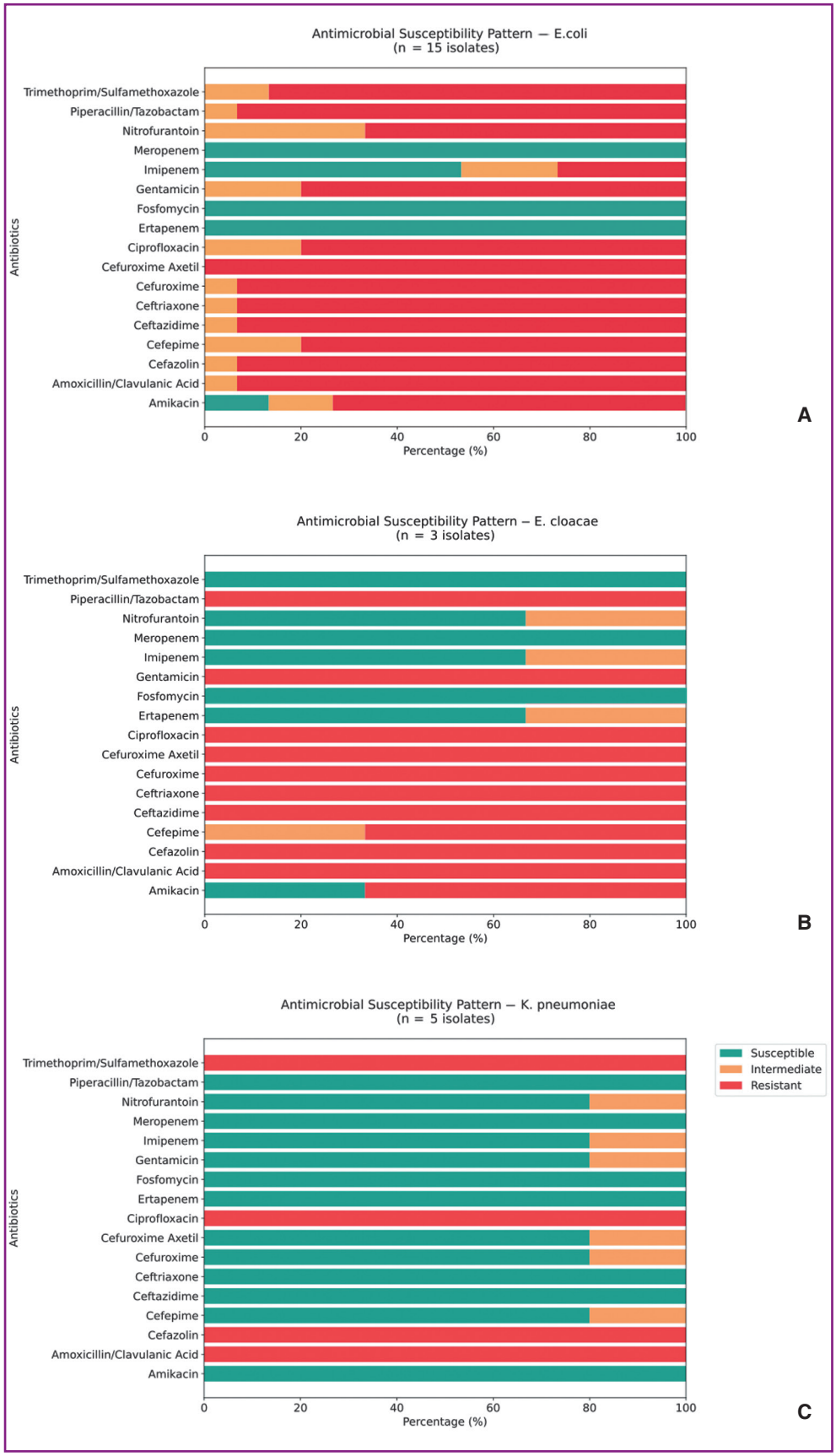

Figure 5. Microbial profile and antimicrobial resistance patterns. Antimicrobial susceptibility profiles for the three most prevalent pathogens: E.coli, K.pneumoniae, and Enterobacter cloacae complex

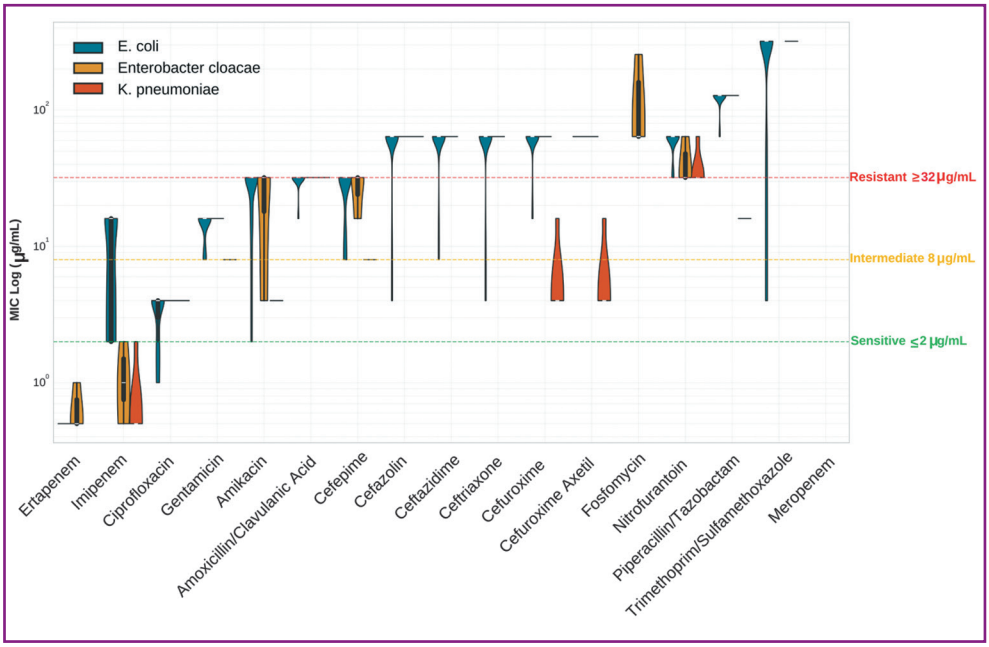

Figure 6. Microbial profile and antimicrobial resistance patterns. Distribution of minimum inhibitory concentrations across different antibiotics and bacterial species

enhanced monitoring and targeted interventions during this critical phase.

Microbial profile and antimicrobial resistance patterns

Among 23 culture-positive samples, the most frequently isolated pathogens were *Escherichia coli* (65.2 %), *Klebsiella pneumoniae* (21.7 %), and *Enterobacter cloacae* complex (13.1 %). Antimicrobial susceptibility testing revealed high resistance rates. *E.coli* showed 93.3 % resistance to beta-lactams but retained 100 % susceptibility to carbapenems (Fig. 5A). *K.pneumoniae* exhibited 100 % resistance to amoxicillin/clavulanic

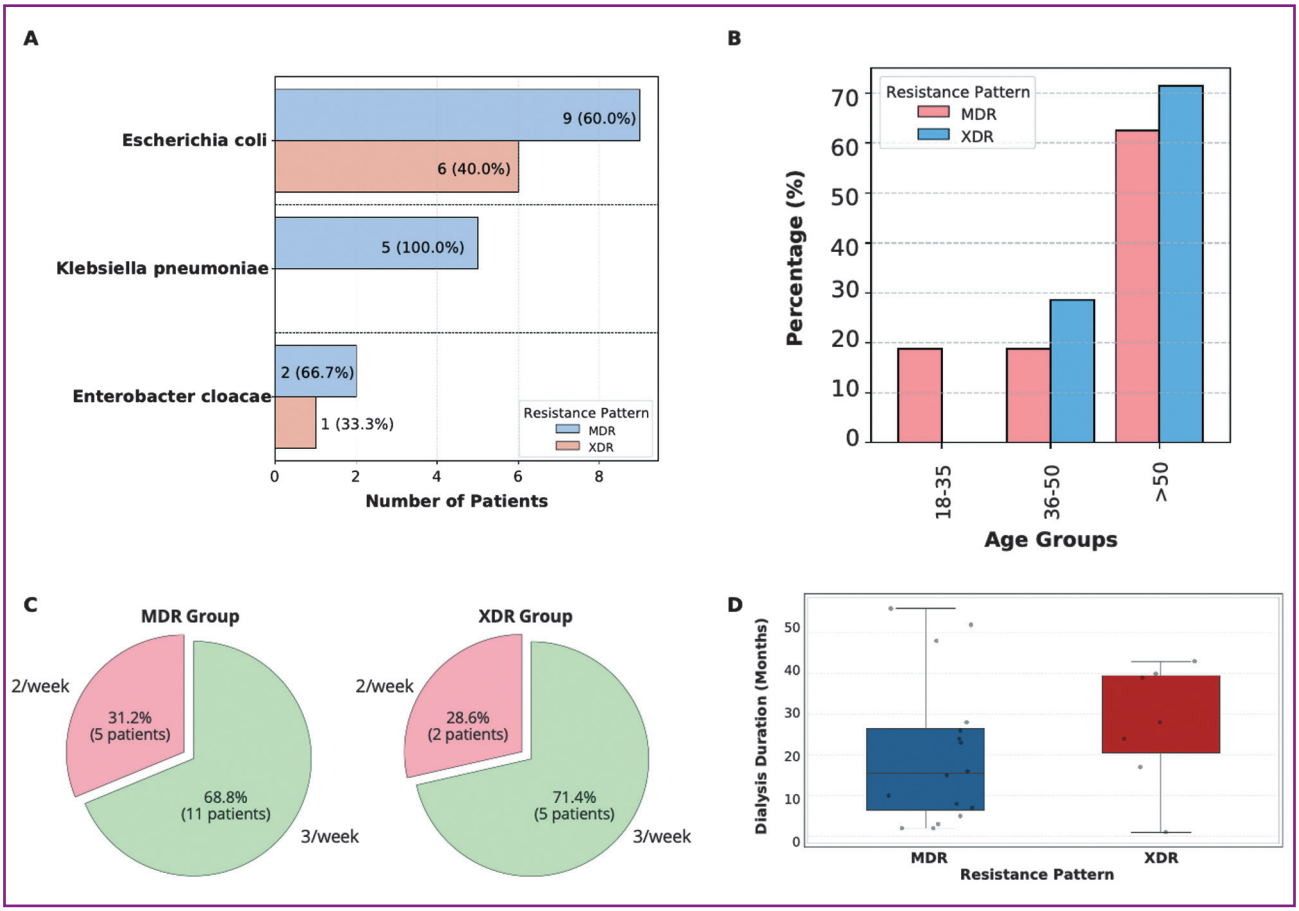

Figure 7. Multidrug resistance and extensively drug resistance in dialysis patients. A. Percentage of MDR and XDR isolates among the most prevalent pathogens. B. Comparison of age distributions between patients with MDR and XDR patterns. C. Distribution of dialysis frequency (number of sessions per week) for MDR and XDR groups. D. Comparison of dialysis duration between MDR and XDR groups

acid, cefazolin, ciprofloxacin, and trimethoprim/sulfamethoxazole (Fig. 5C). *E.cloacae* isolates had 100 % resistance to beta-lactams but were 100 % susceptible to fosfomycin (Fig. 5B).

The extent of multidrug resistance and extensively drug resistance among bacterial isolates from dialysis patients was also examined. Multidrug-resistant (MDR) strains were identified in 60 % of *E.coli* and 100 % of *K.pneumoniae*, while extensively drug-resistant (XDR) strains were found in 40% of *E.coli* and 33.3 % of *E.cloacae* (Fig. 7A). These findings underscore the urgent need for antimicrobial stewardship and targeted infection control strategies in dialysis patients. The analysis of age distribution by resistance pattern revealed notable trends (Fig. 7B). Patients with XDR patterns had a higher mean age (63.7 years) compared to those with MDR patterns (54.9 years). The pie charts reveal distinct patterns in dialysis frequency for both MDR and XDR groups (Fig. 7C). In the MDR group, 68.75 % of patients undergo dialysis 3 times per week, while 31.25 % receive treatment 2 times per week. Similarly, the XDR group shows a comparable distribution, with 71.43 % of patients on a 3-times-per-week schedule and 28.57 % on a 2-times-per-week schedule. The study also analysed dialysis duration patterns between patients with MDR (n = 16) and XDR (n = 7) resistance patterns (Fig. 7D). Patients with XDR demonstrated a longer mean dialysis duration (27.4 ± 15.0 months) compared to those with MDR (20.3 ± 18.0 months). The median dialysis duration was 28.0 months (IQR: 20.5–39.5) in the XDR group and 15.5 months (IQR: 6.5–26.5) in the MDR group. While the XDR group showed a trend toward longer dialysis requirements.

Discussion

Our research offers important insights and knowledge regarding the rate of multidrug-resistant (MDR) and extensively drug-resistant (XDR) bacterial infections, their antimicrobial resistance patterns and clinical implications in dialysis patients. The results show the trends in population, co-morbidities and the burden of antibiotic resistance in this at-risk population, which calls for improvement in infection control measures and antibiotic stewardship programs. The current investigation found that middle-aged individuals are most likely to be on dialysis, with the highest frequency in the 61–70 years age group. This agrees with other studies that have shown that CKD and ESRD mainly affect older people because they have other chronic diseases like diabetes and hypertension [11]. There was near equal distribution of gender, however, the female patients had more age dispersion indicating that dialysis was started at different stages of the disease in women. These demographic findings therefore highlight the need for developing treatment plans that are appropriate for the aging dialysis population.

The high prevalence of diabetes (70 %) as either a single comorbidity or in combination with hypertension and cardiovascular disease supports the notion that diabetes is a major risk factor for the progression of CKD and the need for dialysis. This is in harmony with the global literature that has identified diabetes as one of the leading causes of ESRD. The presence of multiple comorbidities in nearly half of the patients demonstrates the complexity of managing dialysis patients and the importance of multidisciplinary care plans [3, 12]. The results of our analysis revealed that most patients received dialysis treatment three times per week, while a smaller number of patients received dialysis treatment twice per week. Even though dialysis frequency did not affect the infection risk significantly, we noticed an inverse relation between dialysis duration and bacterial infections. Another finding is that patients in their first year of dialysis were most at risk for infections, with culture positivity rates decreasing with increasing duration of dialysis. These findings, therefore, suggest that there is a need to enhance infection prevention measures especially in the initial period of dialysis treatment.

The overall culture positivity rate was 19 % for bacterial infections among dialysis patients. Among culture positives, the most common pathogens were identified as *Escherichia coli* (65.2 %), *Klebsiella pneumoniae* (21.7 %), and *Enterobacter cloacae* complex (13.1 %). This is in agreement with other studies which have established Gram-negative bacteria as the most common cause of blood and urinary tract infections in dialysis patients [13–16]. The most important issue is the role of biofilm formation in catheter related infections. For instance, *K.pneumoniae* and *E.cloacae* are bacteria that can form biofilms which increases their antibiotic resistance and leads to chronic infections in dialysis patients. Further work should be done to reduce this risk, for instance, through the use of antimicrobial coated catheters and agents that disrupt biofilms [17, 18].

The correlation between comorbidities and infection rates was particularly significant. Among the participants, diabetic patients showed the highest rate of culture-positive results (25 %) which is consistent with the literature that states hyperglycaemia, compromises the immune system, and increases the risk of infections [19, 20]. These results therefore suggest that there is a need for early screening and targeted interventions in diabetic dialysis patients. What is curious about this result is that high prevalence of antimicrobial resistance. MDR bacterial strains have been identified in 60 % of *E.coli* isolates whereas *K.pneumoniae* showed 100 %, while the XDR bacterial strains were observed in 40 % of *E.coli* and 33.3 % of *E.cloacae*. The most important result was that the prevalent of resistance to beta-lactams and fluoroquinolones is concerning, since these antibiotics are commonly used in dialysis units. However, carbapenems and fosfomycin were effective against most of the isolates, thus one can consider them as potential options for the treatment of severe infections. Other similar trends have also been reported in other studies [4, 21] which highlights the increasing burden of antimicrobial resistance in dialysis populations world-wide. Hence, carbapenems, fosfomycin, and aminoglycosides should be used to treat severe infections, and beta-lactams and fluoroquinolones should be used only when there is susceptibility testing available.

Conclusions

The significant burden of MDR/XDR infections in dialysis patients underscores the urgent need for specialized infection control measures. To address this, routine MDR/XDR screening should be implemented for all dialysis patients, particularly during the first year of treatment. Additionally, robust antimicrobial stewardship programs must be established to regulate the use of broad-spectrum antibiotics and enhance surveillance of antimicrobial resistance in dialysis units — especially in the Middle East, where regional data remains limited.

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Зростаюча загроза MDR/XDR бактерій у пацієнтів, які перебувають на діалізі: поперечне дослідження

Резюме. Актуальність. Пацієнти, які проходять діаліз, мають підвищений ризик розвитку бактеріальних інфекцій, стійких до множинних лікарських засобів (MDR) та екстремально стійких до лікарських засобів (XDR), через їхню схильність до інфекцій та частий контакт із медичними закладами. **Мета:** визначити рівень поширеності, фактори ризику й антимікробні профілі резистентності цих патогенів для поліпшення догляду за пацієнтами та оптимізації заходів щодо контролю інфекцій. **Матеріали та методи**. Це поперечне дослідження проводилося у відділенні діалізу Навчальної лікарні Аль-Хуссейн міста Ті-Кар/Насірія (Ірак) у період з вересня по грудень 2024 року. У дослідженні взяв участь 121 пацієнт на діалізі. Було зібрано демографічні дані, інформацію про супутні захворювання та параметри, пов'язані з діалізом. Мікробіологічний аналіз включав обробку зразків сечі методом бактеріального посіву, а для ідентифікації бактерій і тестування на чутливість до антимікробних препаратів використовувалася система VITEK 2 Compact. **Результати.** Середній вік учасників становив 55,0 ± 16,6 року, чоловіків було більше (52,9 %), ніж жінок. Найпоширенішою супутньою патологією був цукровий діабет, який вражав 70 % пацієнтів або окремо, або в комбінації з гіпертонічною хворобою та серцево-судинними захворюваннями. Частота позитивних посівів становила 19,0 %, причому *E.coli* була найбільш поширеним збудником (65,2 %), далі йшли *K.pneumoniae* (21,7 %) та *E.cloacae* (13,1 %). Тестування на резистентність показало, що 60 % ізолятів *E.coli* та всі ізоляти *K.pneumoniae* були MDR, тоді як 40 % *E.coli* та 33,3 % *E.cloacae* були XDR. Важливо, що існувала негативна кореляція між тривалістю діалізу й частотою інфекцій ($r = -0,2285$, $p = 0,0117$), що свідчить про те, що інфекції частіше виникають у перший рік діалізної терапії. **Висновки**. Результати підкреслюють значну поширеність MDR/XDR бактеріальних інфекцій серед пацієнтів, які отримують діаліз, особливо на ранніх етапах лікування. Це обумовлює необхідність поліпшення заходів щодо контролю інфекцій, впровадження ефективних програм раціонального використання антибіотиків та регулярного епідеміологічного нагляду в діалізних центрах. Важливо розробити специфічні заходи, спрямовані на зменшення захворюваності й смертності, пов'язаних з інфекціями, серед цієї вразливої групи пацієнтів.

Ключові слова: MDR; XDR; пацієнти на діалізі; хронічна хвороба нирок