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Clinical correlations between catheter-induced urinary tract uropathogens complicating acute pyelonephritis in patients admitted in a teaching hospital

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Mixed Gram-positive bacteria are common isolates, and if left untreated, they can lead to acute and progressive renal damage. This study aims to determine the prevalence and patterns of common bacterial isolates in patients with nosocomial acute pyelonephritis. The study was a cross-sectional descriptive study of 215 patients on in-dwelling catheters. Fifty patients who developed clinical acute pyelonephritis were screened. Catheter urine and tip specimens were collected and sent for microscopic culture and sensitivity testing on MacConkey, CLED, and Blood agar. Data were analyzed using SPSS Statistics version 23.0. A p-value <0.05 was considered statistically significant. Fifty patients with clinical and urine culture-positive results were analyzed. The prevalence of acute pyelonephritis was 23.3%, with 44 (88.0%) males preponderant. The average catheter duration was 6.4+-4.9 days, and was significantly associated with the occurrence of microbial agents. The most common uropathogen identified was *Escherichia coli*. The study revealed that a significant number of patients who developed clinical acute pyelonephritis upon admission were associated with both the underlying aetiopathogenesis and the duration of catheterization. Therefore, prompt surveillance and timely management of patients with catheter-associated urinary tract infections (CAUTIs) are essential to prevent recurrent acute pyelonephritis and subsequent renal damage.

Key words: Bacteria, catheter, urine culture, upper UTI, acute pyelonephritis.

INTRODUCTION

Catheter-associated urinary tract infections (CAUTIs) are reported as the most common hospital-acquired infection (HAI), accounting for approximately 36% of urinary tract infections, followed by surgical site infections and pneumonia (Haque et al., 2018). Patients admitted to intensive care units (ICUs) and requiring prolonged indwelling urethral catheters are particularly at risk, with urinary tract infection rates ranging from 3–5% in United States hospitals. Acute pyelonephritis occurs in 15–25% of CAUTI cases and typically arises from ascending lower urinary tract infections, colonization of the urogenital tract by rectal or perineal flora, or hematogenous spread to the

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kidneys (Li et al., 2023; Rubi et al., 2022). A population-based study in Illinois, USA, reported overall annual incidence rates of 15–17 cases per 10,000 females and 3–4 cases per 10,000 males, reflecting a female preponderance due to the shorter length of the female urethra, which facilitates proximal bacterial seeding (Kilpatrick et al., 2024). The morbidity associated with CAUTI is high, with mortality rates reported up to 37% (Jin et al., 2023). Other complications include lower urinary tract infections (cystitis), septic arthritis, orchitis, osteomyelitis, endocarditis, nephric and perinephric abscesses, sepsis, multiorgan failure, and pan-endophthalmitis (Werneburg, 2022; James et al., 2023). CAUTI-associated acute pyelonephritis can lead to acute kidney injury, and if not promptly treated, may progress to renal scarring, fibrosis, and chronic kidney disease (Hsiao et al., 2015).

The majority of CAUTIs are caused by Gram-negative Enterobacteriaceae, including *Escherichia coli*, *Proteus mirabilis*, and *Klebsiella pneumoniae*, with *E. coli* being the most common. Staphylococcus saprophyticus accounts for 5–10% of cases, while other Gram-negative isolates, such as *Klebsiella* spp. and *Proteus* spp., account for 2–3% (Peng et al., 2018). Upper urinary tract infections may be polymicrobial, involving Gram-negative rods, *Staphylococcus saprophyticus*, *Enterococcus* species, and *Staphylococcus aureus* (Kline and Lewis, 2016), whereas Gram-negative isolates predominate in cystitis (Chou et al., 2022). Candida species, primarily nosocomial, account for 1–3% of cases and are increasingly observed in patients with diabetes mellitus, prolonged catheterization, or repeated antibiotic exposure (Rodrigues et al., 2019). CAUTIs affect the kidneys in approximately 5–9% of patients with indwelling catheters (Zanoni et al., 2021). Management can be challenging due to overlap between lower and upper UTIs, often complicated by antimicrobial resistance (Werneburg, 2022).

Clinical presentations of acute pyelonephritis vary depending on the causative microbes. Antimicrobial therapy is guided by culture and sensitivity results, with appropriate agents or combinations typically achieving pathogen clearance. Gram-positive infections are often associated with high-grade fever, dysuria, urinary urgency, cloudy urine, urinary frequency, costovertebral angle pain, and lumbar tenderness, frequently preceded by at least two days of indwelling catheterization (Kline and Lewis, 2016). Symptoms may be nonspecific, ranging from mild to severe, and can persist for days or weeks. Clinical features of acute pyelonephritis can overlap with those of cystitis, as can their microbial etiologies (Kolman, 2019). Urine culture and sensitivity remain the standard method for identifying site-specific pathogens (Karah et al., 2021).

Upper UTIs, including acute pyelonephritis, may also be diagnosed using markers such as β2-microglobulin, N-acetyl-beta-glucosaminidase (NAG), lactate dehydrogenase isoenzymes, fluorescent antibody-coated bacteria, or Gallium-67 radioisotope imaging (Fritzenwanker et al., 2016). These advanced methods, while highly sensitive, are more costly than conventional urine cultures. Imaging techniques such as computed tomography (CT), magnetic resonance imaging (MRI), and scintigraphy are valuable for diagnosing acute pyelonephritis and its complications but may be inaccessible in resource-limited settings (El-Ghar et al., 2021).

Historically, lower UTIs were considered more common than upper UTIs in catheterized patients. However, recent evidence suggests that upper UTIs are more frequent and have higher case-fatality rates than cystitis (McKertich and Hanegbi, 2021). The clinical course of infection significantly affects therapeutic response; recurrent upper UTIs or acute pyelonephritis can lead to renal scarring and chronic kidney disease if not identified and treated promptly (Olson et al., 2017). CAUTI-associated acute pyelonephritis is linked to prolonged catheterization, increased treatment costs, morbidity (including chronic pyelonephritis or chronic kidney disease), and mortality. This study therefore aims to determine the correlation between patients who present with clinical acute pyelonephritis upon admission and the associated common microbial agents.

METHODOLOGY

This cross-sectional descriptive study was conducted between September 5, 2022, and April 3, 2023. Ethical approval for the study was obtained from the Health Research and Ethical Committee (HREC) of the teaching hospital.

Study population and inclusion criteria

The study included adult patients aged 15 years and above (patients aged 15 years and above are admitted to the adult ward in the study location). A total of 250 patients admitted to the teaching hospital wards for various diagnoses requiring indwelling urinary catheters—such as patients in a coma, postoperative patients, and those with obstructive uropathy—were recruited. The sample size of 250 was calculated using Cochran's (1963) formula for descriptive cross-sectional studies:

$$n = \frac{Z^2 pq}{d^2}$$

where Z represents the confidence interval set at 95%, P is the estimated prevalence (average 17.8%), $q = 1 - P$, and d is the degree of precision. A 10% attrition rate was also considered. Patients who had been on indwelling urinary catheters for more than 2 days and those who developed clinical acute pyelonephritis upon admission—as evidenced by high-grade fever, pyuria, tender renal angle pain, and dysuria—were included following clinical examination and review.

Exclusion criteria

Patients younger than 15 years, those with prolonged antibiotic use

Table 1. Demographic and clinical characteristics of the subjects.

Variable	Frequency (N= 50)	Percentage
Age group (Years)		
≤40	10	20.0
41 – 65	25	50.0
≥65	15	30.0
Mean ± SD	55.1 ± 6.4	
Duration(days)		
1 – 7	42	84.0
8 – 14	5	10.0
>14	3	6.0
Mean ± SD	6.4 ± 4.9	
Sex		
Male	44	88.0
Female	6	12.0

(1–2 weeks), and patients with advanced chronic kidney disease (CKD) who were anuric were excluded from the study.

Sample collection and microbiological analysis

Urine samples were collected using sterile technique and sterile urine bottles. At the microbiology laboratory, samples were cultured on MacConkey agar (for Gram-negative rods), CLED agar (cystine-lactose-electrolyte-deficient, for differentiation of *Proteus* spp.), and Blood agar to promote microbial growth. Plates were incubated at optimal temperatures for 24–48 hours. Bacterial growth was identified based on colony counts, with urinary tract infection (UTI) indicated by ≥100,000 colony-forming units (CFU) per mL. Isolated bacterial colonies were subsequently exposed to commonly used antibiotics, and zones of inhibition were measured to assess susceptibility.

Data analysis

Data were analyzed using SPSS (Statistical Package for the Social Sciences) version 23.0. Categorical variables were presented as frequencies and percentages, while numerical data were presented as mean ± standard deviation. The chi-square test was used to compare categorical variables, and continuous variables were compared accordingly. A p-value < 0.05 was considered statistically significant.

RESULTS

The mean age of the study participants was 55.1 ± 6.4 years, with the majority, 25 (50.0%), aged between 41 and 65 years. The average duration of catheterization was 6.4 ± 4.9 days, and most patients, 42 (84.0%), had a catheter in place for ≤7 days. There were more male patients, 44 (88.0%), than female patients (Table 1). The most common clinical presentations were benign prostatic hypertrophy (BPH) (40.0%), cerebrovascular disease (CVA) (10.0%), chronic liver disease (CLD) (8.0%), and congestive cardiac failure (CCF) (6.0%) (Figure 1). The most frequently isolated organisms were *E. coli* (34.0%), *P. aeruginosa* (24.5%), *K. pneumoniae* (17.0%), and *C. albicans* (7.5%) (Figure 2). Although there was no statistically significant association between the type of organism isolated and the duration of catheterization, the majority of patients with *E. coli* isolates, 7 (38.9%), had been catheterized for more than 6 days (Table 2). The prevalence of acute pyelonephritis among the study participants was 22.3% (Figure 3). A significant association was observed between patient age and the organism isolated, with the majority of *E. coli* isolates, 10 (55.6%), obtained from patients older than 65 years, although 23.6% of all organisms were isolated in this age group (Table 3).

DISCUSSION

Hospital-acquired infections (HAIs) are a significant cause of morbidity and mortality among patients with urinary catheters, particularly those suffering from urosepsis (Gomila et al., 2019). Acute pyelonephritis, a form of upper urinary tract infection (UTI), has been closely associated with the use of indwelling urinary catheters. This study aimed to determine the prevalence of acute pyelonephritis among hospitalized patients and to identify the most common organisms responsible for catheter-associated urinary tract infections (CAUTIs).

Older age is a major host factor predisposing patients to CAUTI, as reported in previous studies (Mishra and Rao, 2019; Ogban et al., 2020). Patients above 74 years often show higher incidence due to physiological changes and comorbidities such as diabetes and malnutrition (Mishra and Rao, 2019; Ogban et al., 2020). In the

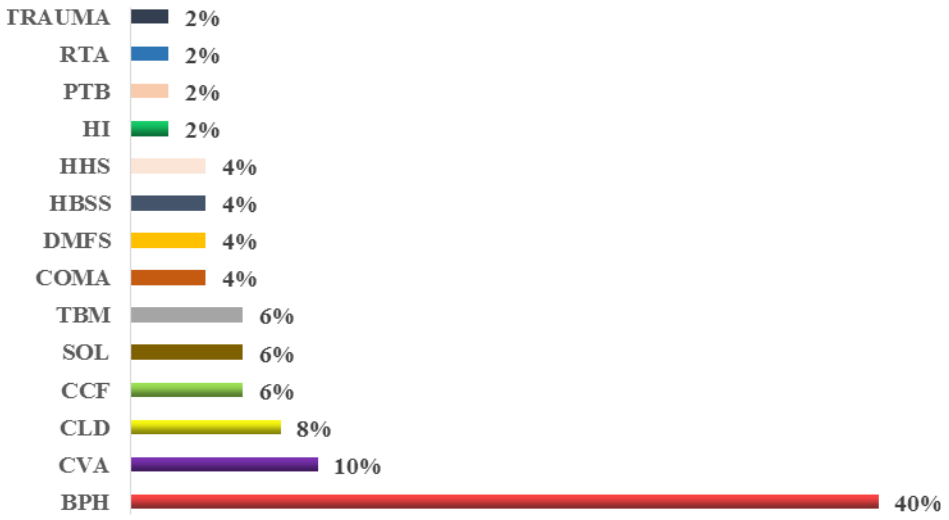

Figure 1. Patterns of clinical diagnosis.
TRAUMA (head trauma), RTA (road traffic accident), DTB (disseminated tuberculosis), HHS (hyperosmolar hyperglycaemic state), (HBSS sickle cell anaemia), DMFS (diabetes foot syndrome), COMA (coma cause), TBM (tuberculous meningitis), SOL (space-occupying lesion), CCF (congestive cardiac failure), CLD (chronic liver disease), CVA (cerebrovascular disease), BPH benign prostatic hypertrophy.

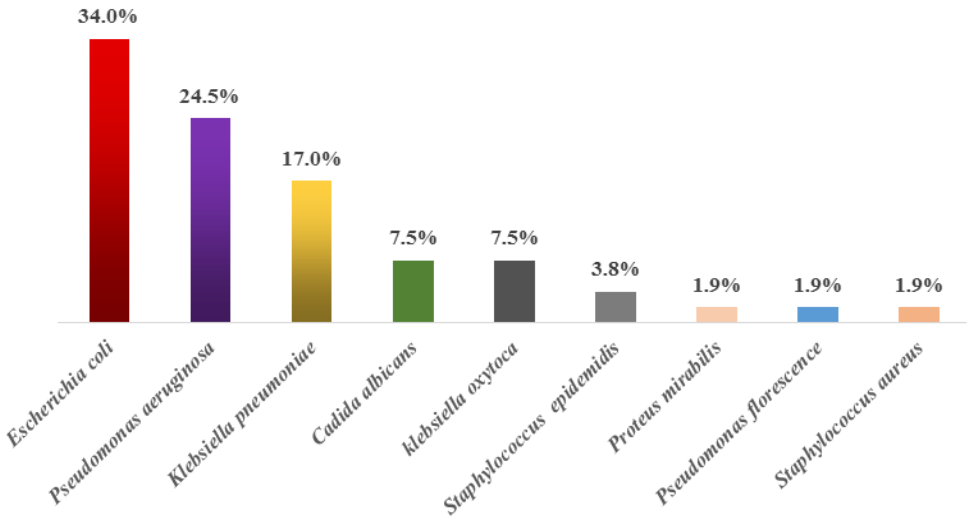

Figure 2. Commonest microorganism.

present study, less than half of the patients were ≤40 years, consistent with previous reports from Europe and the United Kingdom (Perrin et al., 2021). Anatomical differences in the female urogenital system, including a short urethra and proximity to the anus and vagina, predispose females to UTIs, a risk further exacerbated by catheterization (Amadu et al., 2019; Oumer et al., 2021). Interestingly, the present study observed a male predominance with a male-to-female ratio of 7:1. This is likely due to most patients 40% of presenting with benign prostatic hypertrophy (BPH). This aligns with findings from Ilorin, North Central Nigeria (Amadu et al., 2019), but contrasts with reports from Calabar, South Nigeria, which showed a female preponderance (Ogba et al., 2024).

The mean duration of catheterization in this study was 6.4 ± 4.9 days, with most patients having catheters in place for 1–7 days.

Table 2. Association between duration of catheter and microbial growth.

Variable	Duration of catheter			x^2	P-Value
	1 - 3	4 - 6	>6		
Organism					
Candida albicans	0 (00.0)	0 (00.0)	1 (100.0)		
Escherichia coli	5 (27.8)	6 (33.3)	7 (38.9)		
klebsiella oxytoca	3 (75.0)	1 (25.0)	0 (00.0		
Klebsiella pneumoniae	3 (33.3)	3 (33.3)	3 (33.3)	13.236	0.718
Proteus mirabilis	1 (100.0)	0 (00.0)	0 (00.0)		
Pseudomonas aeruginosa	3 (23.1)	3 (23.1)	7 (53.8)		
Pseudomonas florescence	0 (00.0)	0 (00.0)	1 (100.0		
Staphylococcus aureus	1 (100.0)	0 (00.0)	0 (00.0)		
Staphylococcus epidemidis	0 (00.0)	1 (50.0)	1 (50.0)		

X^2= Chi square, *= statistical significance.

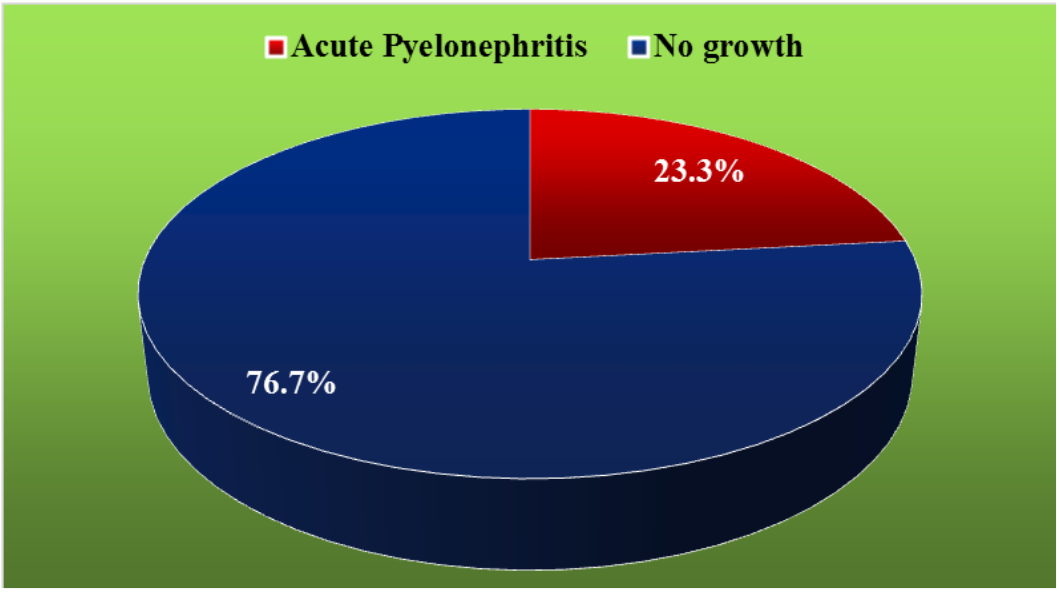

Figure 3. Prevalence of acute pyelonephritis.

Table 3. Association between Age, diagnosis, and microbial growth.

Variable	Age		X^2	P-value
	≤60	Above 60		
Organism				
Candida albicans	0 (00.0)	1 (100.0)		
Escherichia coli	8 (44.4)	10 (55.6)		
klebsiella oxytoca	1 (100.0)	0 (00.0)		
Klebsiella pneumoniae	8 (88.9)	1 (11.1)	14.948	0.013*
Proteus mirabilis	1 (100.0)	0 (00.0)		
Pseudomonas aeruginosa	4 (30.8)	9 (69.2)		
Pseudomonas florescence	1 (100.0)	0 (00.0)		
Staphylococcus aureus	0 (00.0)	1 (100.0)		
Staphylococcus epidemidis	1 (50.0)	1 (50.0)		

This duration is longer than that reported in Southern Ethiopia and South West Nigeria (Oumer et al., 2021; Amisu et al., 2019). This may be possibly due to differences in catheter insertion sites (suprapubic versus urethral), patient clinical presentations, and type of infection. Previous studies consistently show a positive correlation between the duration of catheterization and the risk of developing UTIs, particularly upper UTIs or acute pyelonephritis.

Indwelling urinary catheters are primarily used to relieve urinary obstruction or manage incontinence but inherently increase the risk of infection when used for prolonged periods. In this study, BPH was the most common indication for catheterization, differing from a study in Nigeria where terminally ill patients with diabetic complications and sepsis were the predominant catheterized population.

Microbiologically, *E. coli* was the most commonly isolated organism, accounting for 17 (34.0%) of all isolates, consistent with studies from Ethiopia, India, Nigeria, and the United Kingdom, but contrasting with reports from Saudi Arabia, where *C. albicans* predominates (Lawson et al., 2020; Majumder et al., 2018; Sula et al., 2023; Amisu et al., 2019). Differences in isolation rates may reflect variations in sample size, inclusion criteria, and prior antibiotic use. Furthermore, a significant association was observed between patient age and the organism isolated: the majority of *E. coli* isolates, 10 (55.6%), were from patients older than 60 years.

Comparisons with other studies highlight variability in the dominant uropathogens. For instance, Onipede et al. (2010) reported *Klebsiella oxytoca* as the most frequent isolate in 88 catheterized patients, followed by *Proteus vulgaris*, contrasting with the predominance of *E. coli* in the present study. Untreated upper UTIs can lead to pyogenic scarring and chronic inflammatory changes from recurrent renal parenchymal infections (Ito et al., 2023; Luo et al., 2017). Additionally, improper catheter placement, such as accidental ureteral insertion—particularly in female patients with neurogenic bladders—can precipitate pyelonephritis (Ito et al., 2023; Luo et al., 2017). The prevalence of acute pyelonephritis among catheterized patients in this study was 23.3%, higher than that reported in Baltimore, Maryland, USA (Yu et al., 2020), likely due to differences in catheterization duration and patient demographics.

The overall prevalence of CAUTI in this study was 23.2%, lower than the 57% reported in a multi-center INICC surveillance study of 422 ICUs across 36 countries, which documented 6.3 per 1000 catheter-days in Africa versus 3.3 per 1000 catheter-days in U.S. ICUs (Rosenthal et al., 2012). The lower prevalence in the present study may be attributed to single-center recruitment, a smaller study population, and widespread antibiotic exposure, which can reduce microbial colonization and infection rates (Ling et al., 2023; Rosenthal et al., 2012).

A study in Southwest Nigeria using bladder wash- out techniques reported a CAUTI prevalence of 52.2%, with 42.2% being upper UTIs, predominantly caused by *E. coli* (Amisu et al., 2019). In comparison, the present study reported 23.3% acute pyelonephritis, with *E. coli* remaining the most common isolate, supporting its epidemiological importance in CAUTI pathogenesis.

Conclusion

This study showed that about 23.3% of patients admitted to the wards on urinary catheters developed clinical acute pyelonephritis, which correlated significantly with the occurrence of microbial uropathogens. These findings have instructive implications for prompt and effective antimicrobial application and quality monitoring to prevent recurrent acute pyelonephritis, which may lead to progressive renal impair

CONFLICT OF INTERESTS

The authors have not declared any conflict of interest.

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