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Overview of Catheter-Associated Urinary Tract Infection (CAUTI) Caused by Gram-Negative Pathogens and the Study of Antibiotic-Susceptibility Test Patterns of Bacterial Samples

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Abstract

The increased morbidity and mortality rates in catheter-associated urinary tract infections (CAUTIs) in the hospital environment in recent times are a serious concern today. About 75% of UTIs develop in hospitals, mainly from urinary catheters, which is one of the most common healthcare-associated infections (HAIs) and causes increased healthcare costs and length of hospital stay. According to the CDC 2025 reports, each year, it has been estimated that more than 13,000 deaths are associated with this infection. In this study, *E. coli, Pseudomonas aeruginosa, Klebsiella pneumoniae, Proteus mirabilis, Proteus vulgaris, Acinetobacter baumannii, and Serratia marcescens* are seven gram-negative organisms targeted and tested in an antibiotic susceptibility test (AST) using the disc diffusion method. This study only targets selecting Gram-negative uropathogens to identify the susceptibility rates. *E. coli* (ampicillin, ceftriaxone, ceftazidime, cefataxime, co-trimoxazole, ciprofloxacin, and piperacillin-tazobactam). *P. aeruginosa* showed a high resistance rate to antibiotics such as amikacin, ampicillin, ceftriaxone, cefataxime, co-trimoxazole, and piperacillin-tazobactam. Finally, this study revealed that the most common isolates of *E. coli and Pseudomonas aeruginosa* showed 80% antibiotic resistance compared to other clinical isolates in the AST test.

Key words : Hospital-acquired infection (HAI), Catheter-associated urinary tract infection (CAUTI), Lipopolysaccharide (LPS), antibiotic susceptibility test (AST), Multidrug resistance (MDR).

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Overview : Catheter-associated urinary tract infections (CAUTI) occur when bacteria enter the urinary tract via a urinary catheter[15]. In various hospitals and healthcare facilities, indwelling urinary catheters, especially Foley catheters, are regularly used worldwide[4]. Without any evidence of infectious agents or toxins that infect, incubate, or are present at the time of admission or after 48 hours of admission[15]. The risk of developing a UTI due to frequent stays in the ICU increases the chance of developing CAUTI. Infections happen when pathogens spread to a susceptible host. In modern healthcare, invasive procedures, surgery, indwelling medical devices, and prosthetic devices are associated with these infections. Aseptic techniques of operative or insertion procedures are also patient characteristics that predispose to increased risk rates, such as female gender, paraplegia, cerebrovascular diseases, older age, diabetes mellitus, and geriatric patients[6,12].

They contribute to significant morbidity, mortality, and financial burden on patients worldwide. The urethral catheter is the most prevalent cause of HAI and gram-negative bacteremia[13]. CAUTI and UTI have similar signs and symptoms. Nevertheless, indwelling urethral or suprapubic catheters, intermittent catheterization, or within 48 hours of removal of the catheter. Common signs and symptoms are fever, suprapubic or vertebral angle tenderness, acute hematuria, catheter obstruction, dysuria, urgency, etc. Urosepsis and septicemia can result from CAUTI. Urinary tract organisms that have been inoculated in the bladder are typically the source of infections. These organisms irritate the mucosa and provide bacterial adhesion to the surface, facilitating colonization. They commonly cause infection and are normally seen as multidrug-resistant bacteria and gram-negative organisms of uropathogens[1].

Clinical practice frequently encounters asymptomatic bacteriuria, the presence of bacteria in the urine sample, even without any UTI infection symptoms or signs. This is more common, especially in older people, with women more often than men. Asymptomatic bacteriuria (an individual urine sample where the bacteria are present without any symptoms and signs) is typically considered greater than $>10^5$ CFU/ml in one bacterial species; approximately one lakh bacterial colonies were present. In both catheterized and non-catheterized patients, 10%-30% of bacteriuria is found in their urine to cause catheter-associated in situ bacteriuria[3].

Symptomatic bacteriuria will occur when the bacteria are present in the urine, causing symptoms like frequent urination and burning during urination, and abdominal pain[12]. Symptomatic CAUTI patients experience symptoms like fever, pain in the lower abdomen or back, blood in the urine, foul-smelling urine, and urine leakage in the area around. When CAUTI becomes symptomatic, common symptoms (fever, cystitis, and urethritis) and the serious stage (renal scarring, calculus formation, and bacteremia) are observed[9]. The most common routes of infection are i) short-term catheters, which are the migration of organisms coated on the skin into the catheter tract; ii) at the time of catheter insertion through the urethra; and iii) through the catheter lumen[14].

In biofilm formation, the abiotic catheter surface often makes antibiotic

penetration resistant. Furthermore, antibiotic resistance rates are increasing. The CDC declared in 2013 that the "post-antibiotic era" is now upon the human race, and in 2014, the World Health Organization warned that the antibiotic resistance phenomenon is becoming dire[7]. The symptoms of CAUTI manifest as, compared to the normal range, a rise in body temperature and inflammation of both the urethra and urinary bladder. The serious consequences include renal scarring, calculus formation, acute pyelonephritis, and the presence of bacteria in the bloodstream. These infections can cause urosepsis and even death if not addressed. In general, indwelling HAIs are short-use for fewer than 30 days and long-use for more than 30 days[13].

The diverse Gram-negative culture strain species were collected from various hospitals in Coimbatore using the cultures and further inoculated in blood agar, nutrition agar, and MacConkey agar to create a subculture for further research studies. Gram staining and biochemical tests were used to identify the species, providing additional validation or confirmation of the strains. By using the in vitro technique of the Kirby-Bauer disc diffusion method to determine the susceptibility pattern to test each isolate, seven of the most prevalent gram-negative strains, such as *E. coli, P. aeruginosa, K. pneumoniae, A. baumannii, Proteus mirabilis, P. vulgaris, and S. marcescens*, were employed for the antibiotic susceptibility test to analyze the patterns. More than 95% of all UTIs are caused by a single type of organism. This organism is typically identified through culture and sensitivity testing, which informs the appropriate antibiotic treatment. Understanding these patterns is crucial to developing effective strategies to manage and prevent urinary tract infections[10].

Antibacterial susceptibility Test : This study aimed to determine the susceptibility and resistance rate of gram-negative organisms by using the technique of a modified Kirby-Bauer disc diffusion method to test each isolate for in vitro antibacterial susceptibility tests based on the criteria of the Clinical and Laboratory Standards Institute (CLSI). In brief, to adjust the standard inoculum to 0.5 McFarland, standard turbidity was uniformly spread or distributed over the surface of Mueller-Hinton agar (Hinton Media). The plates were allowed to dry for 3-10 minutes[3]. Antibiotic-impregnated discs are placed in an agar plate with the bacteria. Antibacterial discs are amikacin, ampicillin, ceftriaxone, ceftazidime, cefataxime, co-trimoxazole, ciprofloxacin, gentamicin, and piperacillin-tazobactam. The AST test is useful for analyzing the antibiotics used and the further treatments taken before the diagnosis of CAUTI. Overnight incubation at 37°C, the zone of inhibition was measured and interpreted as sensitive, intermediate, and resistant to the antibiotics selected according to the standard criteria of CLSI guidelines.

Antibacterial Susceptibility Test Pattern of Isolates from Gram-Negative Organisms Report :

Multidrug-resistant bacteria (MDR) to existing medications are one of the biggest challenges facing public healthcare and hospitals. The antibiotic sensitivity test was performed by the Kirby-Bauer disc diffusion method. In clinical isolates of gram-negative organisms, *Escherichia coli and Pseudomonas aeruginosa* were extremely resistant to the

antibiotic resistance pattern of CAUTI Gram-negative organisms, which showed a high resistance pattern in *E. coli* (ampicillin, ceftriaxone, ceftazidime, cefataxime, co-trimoxazole, ciprofloxacin, and piperacillin-tazobactam). *P. aeruginosa* showed a high resistance rate to antibiotics such as amikacin, ampicillin, ceftriaxone, cefataxime, co-trimoxazole, and piperacillin-tazobactam. Antibiotics susceptible in *Proteus mirabilis, P. vulgaris, Acinetobacter baumannii, and Serratia marcescens* showed susceptible rates in ampicillin, ceftriaxone, ciprofloxacin, and gentamicin. K. pneumoniae sensitivity to co-trimoxazole and ciprofloxacin was observed. Antibacterial susceptibilities of the obtained strains were evaluated.

Table-1. Antibiotic Susceptibility Test Pattern of Gram-Negative Organisms from CAUTI

Antibiotics	*A. baum-annii*	*E. coli*	*Klebsiella pneum-oniae*	*P. aeru-ginosa*	*P. mirabilis*	*P. vulgaris*	*S. mar-cescens*
Amikacin	10	22	-	6	11	26	-
Ampicillin	12	-	-	-	18	5	21
Cefataxime	-	-	19	-	19	13	-
Ceftazidime	21	-	-	19	20	-	-
Ceftriaxone	29	-	17	-	17	18	19
Ciprofloxacin	22	-	21	16	21	25	19
Co- trimoxazole	-	-	24	-	-	25	21
Gentamicin	-	24	23	11	16	24	18
Piperacillin+ Tazobactam	11	-	20	-	7	20	17

Bacterial Strains/Zone of Inhibition (mm); No zone of inhibition : (-)

Antibiotic Susceptibility Test:

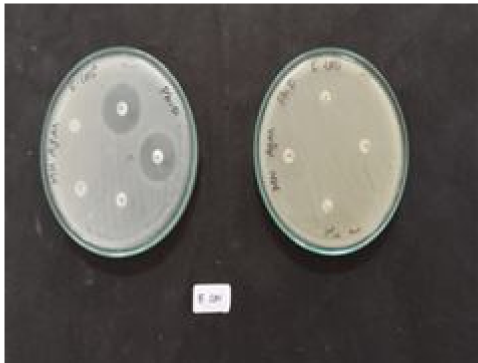

Figure 1

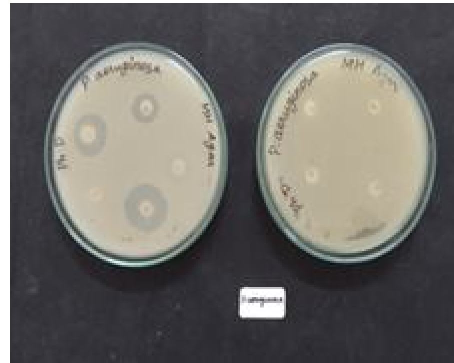

Figure 2

Catheter-associated urinary tract infection is the most widespread infection in many developing countries to cause severe effects both financially and on physical health. This infection is additionally adding to and posing many significant burdens on patients, such as morbidity and mortality. This study not only adds to regional surveillance data but also guides empirical therapy in catheterized patients. This study's findings on antimicrobial resistance patterns in Gram-negative pathogens causing catheter-associated urinary tract infections (CAUTIs) align with global trends. Notably, a high resistance rate to ampicillin (75%) and third-generation cephalosporins was observed, consistent with the 50% resistance to cefotaxime reported[11]. Similarly, a national surveillance study in the United States found that CAUTI pathogens exhibited higher resistance rates to ciprofloxacin (26%) and trimethoprim-sulfamethoxazole (28.1%) compared to non-CAUTI pathogens, underscoring the need for targeted therapy which reported[5] increased resistance to third-generation cephalosporins among CAUTI pathogens in tertiary care centers. Overall, the concordance between our findings and those of previous studies highlights the persistent challenge of antibiotic resistance in CAUTI pathogens. Aminoglycosides are a class of powerful, broad-spectrum antibiotics initially used to target or treat gram-negative infections. They work by inhibiting protein synthesis within the bacterial cells. The consistent efficacy of aminoglycosides suggests their potential as empirical therapy, while the diminished effectiveness of commonly used antibiotics like ampicillin and cefotaxime calls for routine susceptibility testing to guide treatment decisions[8]. In this study, to finalize the gram-negative organisms' antibiotic susceptibility patterns. The combined AST profiling highlights the increasing resistance among Gram-negative uropathogens and underscores the need for targeted antibiotic stewardship.

CAUTIs are the most common healthcare-acquired infection. According to the gram-negative bacteria measures as a surveillance policy to prevent their spread, hand hygiene, isolation, and an antimicrobial stewardship program are a must to identify the causative agents. The AST pattern found in CAUTI is to follow the bundle of CAUTI care strictly[8]. Implementations of infection control and guideline practices must be followed in CAUTI prevention and control of infections and proper care. This may be useful to further the treatment and management of patients in the respective area[13]. This study provides a detailed evaluation of antibiotic resistance patterns among Gram-negative bacterial isolates that are responsible for catheter-associated urinary tract infections (CAUTIs). Through both Antibiotic Susceptibility Testing (AST) analyses, it was evident that resistance to commonly used antibiotics, particularly ampicillin, cefotaxime, and ceftriaxone, is alarmingly high. Higher sensitivity percentages, suggesting their continued reliability in CAUTI treatment. The study aimed to describe prevailing resistance patterns rather than establish causality. Overall, the findings underscore the urgent need for routine surveillance and antibiotic stewardship programs to combat the growing threat of multidrug-resistant Gram-negative uropathogens in hospital settings, especially in patients with prolonged catheterization.

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Conflicts of Interest :

For the current work, the authors have no conflict of interest.

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