DOI: 10.7860/JCDR/2025/76971.20906

Original Article

Microbiology Section

The Burden and Menaces of Catheter associated Urinary Tract Infections in the Patients Admitted at the Critical Care Units: A Cross-sectional Study from a Tertiary Care Centre, Gujarat, India

HIMANI BHARDWAJ PANDYA[1], MOHD TABISH ANSARI[2], NIDHI MIHIR KUMAR BHALODIA[3], SAURABH NORRIS[4], SUCHETA JITENDRA LAKHANI[5]

ABSTRACT

Introduction: Catheter-associated Urinary Tract Infections (CAUTIs) represent a significant global health threat, leading to substantial morbidity and mortality, especially in Intensive Care Unit (ICU) settings.

Aim: To evaluate the rate of CAUTIs and identify patient- and catheter-related risk factors contributing to UTIs and also to characterise the aetiological agents along with their antimicrobial resistance profiles.

Materials and Methods: A cross-sectional study was conducted from October 2021 to September 2022, involving 85 patients with indwelling urinary catheters who had them in place for more than two consecutive days while admitted to the ICUs of a tertiary care centre. Urine samples were cultured and antibiotic susceptibility testing was performed using the Vitek-2 automated system. Data regarding patients' demographic features, co-morbidities, catheterisation checklist and bundle care were collected via a questionnaire. Various patient- and healthcare worker-related risk factors were statistically analysed using p-values and odds ratios.

Results: The CAUTI incidence rate was calculated to be 12.01 per 1000 urinary catheter days. Adherence to hand hygiene (p-value=0.02, OR=2.245), periurethral cleaning (p-value <0.0001, OR=3.675), use of sterile gloves (p-value <0.0001, OR=2.057) and maintenance of a closed drainage system (p-value=0.04, OR=2.057) were significantly associated with a reduced risk of CAUTI. Conversely, being older than 50 years (p-value=0.04, OR=1.650), residing in a rural community (p-value=0.003, OR=3.490), and having hospital stays exceeding seven days (p-value=0.006, OR=3.245) were identified as significant risk factors for the development of CAUTI. The most prevalent uropathogens were *Escherichia coli* (n=17/37, 46%) and *Klebsiella pneumoniae* (n=7/37, 19%), with a high proportion exhibiting Multidrug Resistance (MDR).

Conclusion: To mitigate the burden of CAUTIs, it is essential to prioritise ongoing surveillance within ICUs, implement stringent infection control measures and promote antimicrobial stewardship.

Keywords: Infection control, Intensive care unit, Multidrug resistance, Risk factors

INTRODUCTION

Healthcare-associated Infections (HAIs) are a major cause of morbidity and mortality worldwide [1]. The most prevalent HAIs include CAUTIs, Ventilator-associated Pneumonia (VAP), and Central Line-associated Bloodstream Infections (CLABSIs) [1,2]. According to the Centers for Disease Control and Prevention (CDC) and National Healthcare Safety Network (NHSN) guidelines, CAUTI is defined as a Urinary Tract Infection (UTI) that occurs when an indwelling urinary catheter has been in place for more than two consecutive days in an inpatient location on the date of the event, with the day of device placement considered day 1. Additionally, an indwelling urinary catheter must have been in place on the date of the event or the day before [3].

Globally, CAUTI is regarded as the most prevalent HAI, accounting for up to 40% of all HAIs, with indwelling urinary catheters responsible for approximately 70-80% of UTIs in healthcare settings [3]. In ICUs, devices are used on average 45-79% more frequently than in hospital wards (17-23%). This higher usage contributes to the significant public health concern of infections, leading to longer hospital stays, increased healthcare costs and a surge in morbidity and mortality [4,5].

The most predictable causes of CAUTI include both the process of catheterisation and the duration of catheterisation. Additional risk factors may include improper catheter insertion, inadequate aseptic technique, poor hand hygiene, lack of asepsis at the urethral orifice, colonisation of the drainage bag, underlying illnesses, and older age [6]. CAUTI can lead to several complications such as prostatitis, epididymitis, cystitis, pyelonephritis, osteomyelitis, meningitis and sepsis in patients. Microorganisms can enter the urinary tract through either intraluminal spread (e.g., an open drainage bag or a hole in the closed drainage system) or extraluminal spread (e.g., the patient's endogenous flora or hands of healthcare workers) [7].

In ICUs within low- and middle-income countries, the incidence of CAUTI ranges from 5.5 to 8.8 per 1000 catheter days [8]. Pooled data from India report a CAUTI incidence of 1.60, which is significantly lower than the CDC-NHSN benchmark of 2.09 and the INICC benchmark of 6.5 [9-11]. Despite advancements in infection control practices in ICUs, CAUTI remains a substantial burden to both patients and hospitals. The incidence of CAUTI is not declining, highlighting the need for a deeper understanding of the factors contributing to CAUTI development. Therefore, mandatory periodic surveillance of CAUTIs in the ICU is essential.

In this context, the study aimed to determine the incidence rate of CAUTIs, identify their aetiology and antimicrobial resistance profiles, analyse patient and healthcare worker-related actionable risk factors for CAUTIs, and provide evidence-based recommendations for their prevention based on the study's findings.

MATERIALS AND METHODS

This cross-sectional study was conducted in the microbiology laboratory of a tertiary care hospital in Vadodara, Gujarat, India. The study was conducted over a one-year period, from October 2021 to September 2022. Approval was obtained from the Institutional Ethical Committee (IEC) prior to the initiation of the study (Dated: 12/10/2021, Approval No.: SVIEC/ON/Medi/BNPG20/D21160). All eligible samples collected during the study period were included in the study.

Inclusion criteria: Patients admitted to critical care units with an indwelling urinary catheter that had been in place for more than two consecutive days in an inpatient location on the date of the event, or who had the catheter removed the day before the date of the event (according to the CDC NHSN guidelines), were included in the study [3].

Exclusion criteria: Catheterised patients aged less than two years, patients displaying signs and symptoms of UTI within two calendar days of catheterisation, and patients with condom catheters or suprapubic catheters were excluded from the study.

Study Procedure

Data were collected regarding demographic details (age, gender, occupation, education, residence and socio-economic status [10], such as rural or urban), date of admission, date of catheterisation, duration of catheterisation, indication for catheterisation, co-morbidities (such as diabetes and hypertension) and antibiotic therapy using a questionnaire. Patients were monitored from the time of inclusion in the study until the date of catheter removal and followed-up for one day after removal to check for signs and symptoms suggestive of UTI. Data regarding the infection control practices followed by healthcare workers were also recorded using a checklist designed for CAUTI as per the NHSN guidelines.

Sample collection: After proper disinfection of the catheter sample collection port with 70% Isopropyl Alcohol (IPA), urine samples were collected in wide-mouth, leakproof, sterile containers. Cultures were conducted using a calibrated loop (0.001 mL) on sterile Hi-Chrom agar, MacConkey's agar plates, and Cysteine Lactose Electrolyte-Deficient (CLED) media (media procured from Hi Media Labs, Mumbai) through both streaking and semiquantitative methods. The colonies were subsequently identified using antimicrobial susceptibility testing with the Vitek-2 compact system (Bio Mérieux). Antibiotic sensitivity testing was performed using the Minimum Inhibitory Concentration (MIC) method, in accordance with the Clinical and Laboratory Standards Institute guidelines (CLSI-M100-Ed 31) [12].

Multi-Drug Resistance (MDR): MDR is defined as acquired Non susceptibility to at least one agent in three or more antimicrobial categories [12].

According to the CDC NHSN guidelines [3], the surveillance criteria for CAUTI (Symptomatic Urinary Tract Infections [SUTI 1a] criteria, CDC NHSN) were met only if all three NHSN surveillance diagnostic criteria were fulfilled:

- Catheter in place for more than two calendar days.
- Presence of at least one symptom such as fever >38°C, suprapubic tenderness, or costovertebral angle pain.
- Growth of a significant number (≥10^5 CFU/mL) of uropathogens.

STATISTICAL ANALYSIS

Data were entered into Microsoft Excel and analysed using the Statistical Package for the Social Sciences (SPSS) software, version 23.0 for Windows. Categorical variables were summarised as frequencies and percentages. To assess the association between potential risk factors and the occurrence of CAUTI, odds ratios (OR) with 95% confidence intervals (CI) were calculated. The Chi-square test was used to compare categorical variables between CAUTI and non-CAUTI groups. A p-value of <0.05 was considered statistically significant for all analyses.

RESULTS

A total of 85 critically ill patients admitted to the Medical Intensive Care Unit (MICU) and Paediatric Intensive Care Unit (PICU) were enrolled in the study. Patients were included based on specific criteria, encompassing a diverse range of co-morbidities and clinical presentations. The cohort comprised 43 males (50.6%) and 42 females (49.4%), with an age range of 10 to 80 years. Most patients 55 (64.7%) originated from rural areas, while the remaining 30 (35.3%) were urban residents. The primary diagnoses for ICU admission included acute kidney injury, chronic kidney injury, acute cerebrovascular accident, altered mental status and urosepsis. Additionally, a significant proportion of patients had underlying co-morbidities: Diabetes Mellitus (DM) 12 (14.1%), hypertension 11 (12.9%), or both 7 (8.5%).

Catheterisation duration and CAUTI incidence: The duration of catheterisation varied among patients. A substantial number 63 (74.1%) required catheterisation for more than seven days, while 15 (17.7%) and 7 (8.2%) had catheters for four to seven days and less than four days, respectively. Of the 85 catheterised patients, 37 (43.5%) developed CAUTI, as defined by the Symptomatic Urinary Tract Infection (SUTI 1a) criteria [3]. The overall CAUTI incidence rate was calculated as 12.01 per 1000 catheter-days, using the CDC NHSN formula [3].

CAUTI incidence rate=Number of CAUTI cases×1000

Total number of Urinary catheter -days

=37×1000/3079 catheter days

=**12.01/1000 urinary catheter days**

Escherichia coli was the most prevalent causative agent of CAUTI, accounting for 17 (20%) cases. Other significant pathogens included *Klebsiella pneumoniae* 7 (8.2%), *Pseudomonas aeruginosa* 4 (4.7%), *Candida albicans* 4 (4.7%), and *Enterobacter cloacae* 2 (2.4%). Less common isolates included *Proteus mirabilis*, *Providencia rettgeri*, and *Acinetobacter baumannii* 1 (1.2%).

A multivariate analysis identified several modifiable risk factors associated with CAUTI rates [Table/Fig-1].

Characteristics		Total (n=85)	CAUTI (n=37)	No signs of CAUTI (n=48)	Chi-square	p-value	Odd ratio	Confidence interval
Techniques for urinary catheter insertion								
Hand hygiene before and after insertion	Yes	77 (90.6%)	30 (39%)	47 (61%)	5.1118	0.02	2.245	1.2841-93.651
	No	08 (9.4%)	07 (87.5%)	01 (12.5%)				
Properly trained person	Yes	79 (92.9%)	32 (40.5%)	47 (59.5%)	4.1609	0.04	2.057	0.8190-65.852
	No	06 (7.1%)	5 (83.3%)	1 (16.7%)				
Using sterile gloves	Yes	66 (77.6%)	20 (30.3%)	46 (69.7%)	21.012	<0.0001	2.057	4.1230-92.700
	No	19 (22.4%)	17 (89.5%)	2 (10.5%)				

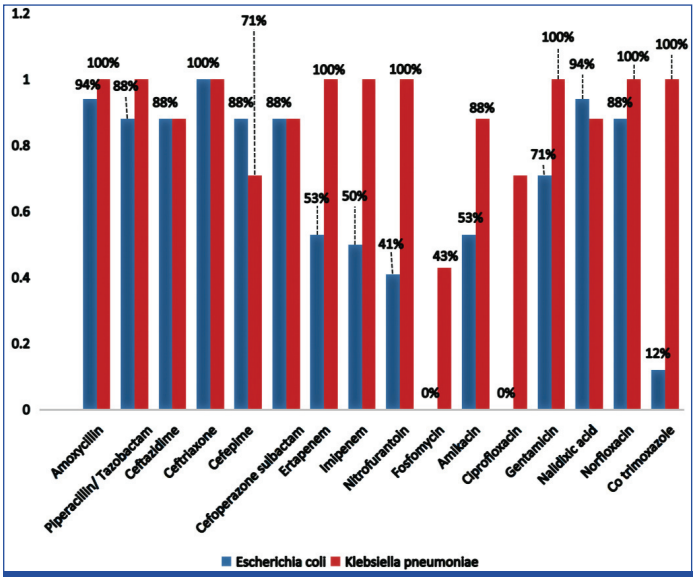
Periurethral cleaning	Yes	49 (57.6)	10 (20.5%)	39 (79.5%)	25.161	<0.0001	3.675	4.1955 to 32.6275
	No	36 (42.4%)	27 (75%)	9 (25%)				
A single-use packet of lubricant jelly	Yes	61 (71.8%)	23 (37.7%)	38 (62.3%)	2.2015	0.13	0.547	0.8833 to 6.0570
	No	24 (28.2%)	14 (58.3%)	10 (41.7%)				
Factors associated with urinary catheter maintenance								
Maintain a closed drainage system	Yes	79 (92.9%)	32 (40.5%)	47 (59.5%)	4.1609	0.04	2.057	0.8190-65.852
	No	06 (7.1%)	5 (83.3%)	1 (16.7%)				
Maintain unobstructed urine flow	Yes	77 (90.6%)	33 (42.9%)	44 (57.1%)	0.1504	0.68	1.166	0.3104 to 5.7274
	No	8 (9.4%)	4 (50%)	4 (50%)				
Use standard precautions, including the use of gloves and a gown	Yes	61 (71.8%)	20 (32.8%)	41 (67.2%)	10.142	0.0006	2.160	1.7777 to 13.9430
	No	24 (28.2%)	17 (70.9%)	7 (29.1%)				
Use of systemic antibiotics	Yes	6 (7.1%)	4 (66.7%)	2 (33.3%)	1.4059	0.23	0.626	0.0620 to 2.0751
	No	79 (92.9%)	33 (41.8%)	46 (58.2%)				

[Table/Fig-1]: Analysis of various risk factors (Related to the health care worker) associated with CAUTI and NON-CAUTI patients.

Adherence to hand hygiene practices before and after catheter insertion was significantly associated with a reduced risk of CAUTI (p-value=0.02, OR=2.245). Proper periurethral cleaning was strongly associated with a decreased risk of CAUTI (p-value <0.0001, OR=3.675). The use of sterile gloves during catheter insertion significantly reduced the risk of CAUTI (p-value <0.0001, OR=2.057). Maintaining a closed drainage system was associated with a lower risk of CAUTI (p-value=0.04, OR=2.057). Adherence to standard precautions significantly reduced the risk of CAUTI (p-value=0.0006, OR=2.160). In contrast, the use of single-packet jelly (p-value=0.13) and empirical antibiotic therapy (p-value=0.23) did not significantly impact CAUTI rates.

The analysis of patient-related risk factors associated with CAUTI shows that patients aged over 50 years were significantly more likely to develop CAUTI (p-value=0.04, OR=1.650). Patients from rural communities had a significantly higher risk of CAUTI (86% of cases, p-value=0.003, OR=3.490). Patients with a hospital stay of more than seven days were at significantly increased risk of CAUTI (90% of cases, p=0.006, OR=3.245). Patients admitted to the Medical ICU had a significantly higher risk of CAUTI (p-value=0.08, OR=5.351). Gender (male vs. female) was not found to be a significant risk factor for the development of CAUTI (p-value=0.92, OR=0.969).

[Table/Fig-2] shows that most *Escherichia coli* and *Klebsiella* species were MDR.



[Table/Fig-2]: Resistance pattern of *Escherichia coli* and *Klebsiella pneumonia*.

Escherichia coli exhibited 100% resistance (n=17/17) to ceftriaxone, 94% resistance (n=16/17) to amoxicillin, nalidixic acid, and ticarcillin, and 88% resistance (n=15/17) to norfloxacin, ceftazidime, and piperacillin/tazobactam. However, it demonstrated 100% sensitivity (n=17/17) to ciprofloxacin and fosfomycin, 47% sensitivity (n=8/17) to carbapenems, and 59% sensitivity (n=10/17) to nitrofurantoin.

Klebsiella pneumoniae strains showed absolute resistance (n=7/7, 100%) to amoxicillin, piperacillin/tazobactam, ceftriaxone, imipenem, nitrofurantoin, gentamicin, norfloxacin, and cotrimoxazole. They also exhibited 88% resistance to ceftazidime, cefoperazone/sulbactam, amikacin, and nalidixic acid, and 71% (n=5/7) resistance to cefepime and ciprofloxacin. Only 57% (n=4/7) of strains demonstrated sensitivity to fosfomycin.

Enterobacter cloacae: Showed 100% resistance (n=2/2) to cefepime, nitrofurantoin, and fosfomycin. Additionally, 50% resistance (n=1/2) was observed towards amoxicillin, piperacillin/tazobactam, ceftazidime, ceftriaxone, cefoperazone/sulbactam, imipenem, amikacin, ciprofloxacin, gentamicin, norfloxacin, and nalidixic acid.

Proteus mirabilis and *Providencia rettgeri* strains exhibited 100% resistance to all tested antibiotics. *Pseudomonas aeruginosa* demonstrated 100% resistance (n=4/4) to tigecycline and 75% resistance (n=3/4) to piperacillin/tazobactam, ceftazidime, imipenem, meropenem, ciprofloxacin, levofloxacin, and co-trimoxazole. Minocycline (n=3/4, 75%) was the most sensitive antibiotic, followed by 50% sensitivity (n=2/4) towards cefoperazone/sulbactam, cefepime, amikacin, and gentamicin.

Acinetobacter baumannii exhibited 100% resistance to ticarcillin, imipenem, gentamicin, levofloxacin, and ciprofloxacin, while all strains were sensitive to tigecycline, co-trimoxazole, ceftazidime, cefepime, cefoperazone/sulbactam, and piperacillin/tazobactam.

DISCUSSION

More than five million ICU patients annually undergo catheterisation, significantly increasing their risk of developing CAUTIs and associated complications. Urinary catheters are widely recognised as the primary risk factor for UTIs worldwide. However, multiple factors, such as aseptic technique, hand hygiene, catheter care and duration of catheterisation, influence the incidence of CAUTIs [13,14]. Therefore, a comprehensive approach is essential to reduce CAUTI rates. Given the higher incidence of catheterisation in ICUs compared to general wards, this prospective observational study was conducted at a rural tertiary care hospital to monitor CAUTI incidence over one year.

The overall CAUTI incidence in this study was 43.5% (37/85), which aligns with the findings of Anggi A et al., (44.4%) in 2019 [15]. However, it exceeds the rates reported by Verma S et al., (15.95%) in 2017 and Parihar S et al., (14.67%) in 2023 [16,17]. The calculated CAUTI incidence rate of 12.01 per 1000 catheter days was comparable to the rate reported by Habibi S et al., at AIIMS New Delhi (11.3%) [18]. However, it is lower than the rates

observed in the multicentre International Nosocomial Infection Control Consortium (INICC) [19] study in Mongolia (15.7%), as well as those reported by Kashyap B et al., (17.38%) and Shrestha SK et al., (30.21%) [20,21]. The overall CAUTI infection rate in seven Indian hospitals participating in the INICC was 1.41 per 1000 catheter days [22]. In the southeastern part of Asia, Europe, and the South and North Americas, the occurrence of catheter-acquired urinary tract contamination per 1,000 catheter days was 15.71, 8.99, and 5.70, respectively, with a mean level of 8.50 [22].

Although the CAUTI rates in the present study do not align with the pooled data from India, they also reveal considerable disparities from place to place. This undoubtedly indicates that strict adherence to catheter care bundles, the implementation of infection control practices, and proper hand hygiene compliance should be enforced in all hospitals to reduce the burden of CAUTIs. This study did not identify a significant gender predisposition for CAUTI; males (50.6%) and females (49.4%) were equally likely to develop the infection. These findings challenge the traditional belief that women, due to their shorter urethras, are more susceptible to UTIs.

The most common aetiology was *Escherichia coli* (45%), followed by *Klebsiella pneumoniae* (19%) and *Pseudomonas aeruginosa* (11%), which was consistent with findings from other studies [14,15]. It has been reported that 40–72% of CAUTIs worldwide are due to *Escherichia coli* [23,24]. Uropathogenic *Escherichia coli* plays an important role in pathogenesis as it possesses type I pili capable of binding to the urinary epithelium, thereby preventing their elimination by urine flow [25,26]. Capsules and lipopolysaccharides also help evade the host immune system. Similarly, *Klebsiella pneumoniae* is identified as the second most common causative agent of CAUTI, accounting for approximately 8–16% of cases [25]. It also expresses type 1 pili to adhere to the catheter, resulting in the initiation of biofilm formation and bladder colonisation [27]. Four cases (11%) of CAUTIs were due to the pathogenic yeast, *Candida albicans*, which aligns well with the results of the study by Verma S et al., [16].

The present study emphasises the role of various modifiable risk factors, such as techniques for urinary catheter insertion, including performing hand hygiene before and after insertion (OR=2.245), periurethral cleaning (OR=3.675), and the use of sterile gloves (OR=2.057). Additionally, urinary catheter maintenance practices, like maintaining a closed drainage system (OR=2.057), were significantly associated with a reduction in CAUTI rates. The study highlights that failure to perform hand hygiene before the insertion of a catheter doubles the risk of CAUTI; similarly, neglecting periurethral cleaning increases the risk by 3.5 times. A hospital stay of more than seven days is also directly proportional to the risk of CAUTI and increases the risk threefold. The longer the stay, the more catheter days accumulate, which is a significant risk factor for developing bacteriuria. Many authors have highlighted that the duration of catheterisation increases the risk by 3-7% daily [27]. Numerous studies indicate that the longer a catheter remains indwelling in the urethra, the higher the rate of bacterial colonisation in the urinary bag and the ascending drainage tubing towards the bladder, resulting in CAUTI [27-29].

Co-morbidities such as DM are significant factors contributing to CAUTIs. DM can cause incomplete bladder emptying and lead to microorganism colonisation. In present study, 48% of cases demonstrated co-morbidities, with DM occurring in the largest number of cases at 14%. Additionally, DM with hypertension was observed in 8% of cases, which was comparable to several other studies [14,27,30].

The antimicrobial susceptibility pattern of the isolates obtained in this study revealed that most of the Gram-negative bacilli were MDR. There were significant variations in susceptibility patterns among the isolates. The resistance patterns are largely consistent with findings from other studies [26,30,31]. The high resistance rate observed in present study may be attributed to the study's design, which focused on ICU patients. With varied co-morbidities, the emergence of MDR pathogens is indeed a significant concern for microbiologists and healthcare professionals. The presence of MDR pathogens among the isolates, even within a smaller sample size, underscores the urgency of evaluating the effectiveness of care bundles and other preventive measures. Consequently, the antibiotic stewardship programme plays an important role in hospitalised patients with UTIs, as it is frequently encountered by treating physicians.

Limitation(s)

The primary limitation of this study was the small sample size, as it was conducted exclusively on ICU patients. Expanding the study duration to include In-patient Department (IPD) patients could provide a more comprehensive analysis. Due to the limited sample size of 37 isolates, authors were unable to make substantial observations on the resistance patterns.

CONCLUSION(S)

CAUTI incidence rates were high in the ICU in present study. However, by addressing modifiable risk factors, particularly catheter bundle care such as hand hygiene practices, periurethral cleaning, the use of sterile gloves and maintaining a closed drainage system, these rates can be substantially reduced. Continuous surveillance of the ICU is essential. Adhering to the aforementioned practices can also help reduce the spread of MDR organisms causing CAUTI. Since the isolates in present study were MDR, this suggests a need for an effective antibiotic stewardship programme.

Acknowledgement

The authors thank the Infection Control Nurse for providing accurate data on CAUTI patients and Infection control practices followed in ICUs.

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PARTICULARS OF CONTRIBUTORS:
1. Associate Professor, Department of Microbiology, Smt B.K. Shah Medical College and Research Centre, Sumandeep Vidyapeeth (Deemed to be a University), Vadodara, Gujarat, India.
2. Tutor, Department of Microbiology, Ananya College of Medicine and Research Ahmedabad Mehsana High Way, Kalol, Gandhinagar, Gujarat, India.
3. Associate Professor, Department of Microbiology, Smt. Bhikhiben Kanji Bhai Shah Medical Institute and Research Centre, Sumandeep Vidyapeeth (Deemed to be a University), Vadodara, Gujarat, India.
4. Associate Professor, Department of Microbiology, Smt. Bhikhiben Kanji Bhai Shah Medical Institute and Research Centre, Sumandeep Vidyapeeth (Deemed to be a University), Vadodara, Gujarat, India.
5. Professor, Department of Microbiology, Smt. Bhikhiben Kanji Bhai Shah Medical Institute and Research Centre, Sumandeep Vidyapeeth (Deemed to be a University), Vadodara, Gujarat, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Himani Bhardwaj Pandya,
Smt. Bhikhiben Kanjibhai Shah Medical Institute and Research Centre,
Sumandeep Vidyapeeth (Deemed to be a University), Vadodara-391760,
Gujarat, India.
E-mail: himani22pandya@yahoo.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Nov 25, 2024
- Manual Googling: Mar 19, 2025
- iThenticate Software: Mar 21, 2025 (15%)

ETYMOLOGY: Author Origin

EMENDATIONS: 6

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Nov 24, 2024**
Date of Peer Review: **Jan 31, 2025**
Date of Acceptance: **Mar 23, 2025**
Date of Publishing: **Apr 01, 2025**