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Factors That Affect Nosocomial Catheter-Associated Urinary Tract Infection in Intensive Care Units: 2-Year Experience at a Single Center

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Purpose: This study took a retrospective approach to investigate patients with catheter-associated urinary tract infection (CAUTI) over 2 years at a single hospital's intensive care unit (ICU) to identify meaningful risk factors and causative organisms.
Materials and Methods: A retrograde analysis was performed on patients with indwelling catheters between January 2009 and December 2010 in Yeouido St. Mary Hospital medical and surgical ICU. CAUTI was defined as isolated bacterial growth of 100,000 colony-forming units or more either 48 hours after transfer to the ICU if a urinary catheter was placed before the transfer or 48 hours after insertion if the catheter was inserted in the ICU. Only the patients whose culture results were negative before ICU admission were included.
Results: There were a total of 1,315 patients with indwelling urinary catheters in our hospital's medical and surgical ICU between January 2009 and December 2010. Of these patients, 241 had positive urine culture results, and 61 had CAUTI. Using multivariate logistic regression analysis, those with diabetes were 4.55 ($p<0.001$) times as likely to have occurrences of CAUTI than were those without and also had a 1.10-fold ($p<0.01$) longer duration of an indwelling catheter. Upon urine culture, among the 61 patients with CAUTI, *Escherichia coli* was the most common bacterium grown; it was identified in 24 patients (38.7%).
Conclusions: The factors and causative organisms contributing to the development of CAUTI in the management of ICU patients must be considered to prevent the occurrence of UTIs in this setting.

Keywords: *Catheters; Intensive care units; Urinary tract infections*

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INTRODUCTION

Nosocomial infections have a significant influence on patient morbidity and mortality. Despite the efforts of health care professionals and the development of new antibiotics, the incidence of nosocomial infections has not decreased [1]. Urinary tract infections (UTIs) comprise 30% to 40% of all nosocomial infections, with UTIs occurring in intensive care units (ICUs) comprising 8% to 21% of all nosocomial infections [2,3]. According to a large surveillance program in Europe across 1,417 ICUs, UTIs were the third most common type of infection occurring in ICUs after pneumonia and lower respiratory tract infections [4].

The leading cause of nosocomial UTI is the presence of an indwelling catheter; the incidence of UTIs among hospitalized patients with indwelling catheters is approximately 15% [5]. Because patients in ICUs frequently require careful monitoring of intake and output and many of them use a urinary catheter, the risk of UTI is significantly higher than in other patient populations. Furthermore, because most patients admitted to ICUs have significant complications and are sicker than other patients, the effects of catheter-associated urinary tract infection (CAUTI) are more critical. This study took a retrospective approach to investigate patients with CAUTI over 2 years at a single hospital's ICU to identify meaningful risk factors and causative organisms.

MATERIALS AND METHODS

1. Subjects and methods

A retrograde analysis was performed on patients with indwelling catheters between January 2009 and December 2010 in Yeouido St. Mary Hospital medical and surgical ICU. CAUTI was defined as isolated bacterial growth of 100,000 colony-forming units or more either 48 hours after transfer to the ICU if a urinary catheter was placed before the transfer or 48 hours after insertion if the catheter was inserted in the ICU. Only the patients whose culture results were negative prior to ICU admission were included. To differentiate between asymptomatic bacteriuria (ASB) and UTI, patient records were investigated for the presence of fever (temperature greater than 37.8°C) at the time of positive urine culture results; those results exhibiting ASB were excluded. The control group consisted of ICU patients with indwelling catheters who had negative urine culture results before and after ICU transfer (48 hours post-transfer to discharge from the ICU) and the absence of fever (temperature greater than 37.8°C). Patients who died in the ICU and those with longstanding indwelling urinary catheters (30 days or more) before ICU transfer were excluded from this study.

The demographic and clinical data collected were as follows: age, gender, presence of diabetes, recent surgery, length of ICU stay, location of catheter insertion, previous antibiotic use, presence of ventilator, and severity score at ICU admission (Simplified Acute Physiology Score [SAPS] II). Recent surgery was defined as surgery under general endotracheal anesthesia within 7 days before urinary catheter insertion and previous antibiotic use was defined as patients given antibiotics for either preventive or therapeutic purposes when the urethral catheter was being inserted.

Only silicone catheters were used for urinary catheters, and careful attention was given to the drainage system, disposing of the urine accumulated in the collection bag, replacing a malfunctioning collecting system, and keeping the system closed. The indwelling urethral catheters were inserted after wearing sterile gloves and using sterile drapes. Routine meatal and perineal hygiene with povidone-iodine, water, and nonsterile gloves was performed once daily and routine catheter change was done every second week.

Urine collection was performed with a sterile syringe after wiping the catheter end with a boric sponge. Bacteria in the collected urine were identified by using an ATB kit from bioMérieux SA (Marcy l'Etoile, France), and the antibiotic sensitivities were tested by using the Kirby-Bauer method.

2. Statistical analysis

Statistical analysis was performed by using the IBM SPSS ver. 19.0 (IBM Co., Armonk, NY, USA). Univariate analysis was conducted to determine potential risk factors for bacteriuria occurrence. The χ^2 or Fisher's exact test was used for qualitative variables, and Student's t-test was used for quantitative variables. The required significance level was set at a p-value less than 0.05. Multivariate analysis quantified the respective effect of each variable on the occurrence of bacteriuria.

RESULTS

1. Patient population

There were a total of 1,315 patients with indwelling urinary catheters in our hospital's medical and surgical ICU between January 2009 and December 2010. Of these patients, 241 had positive urine culture results, 61 had CAUTI as defined in this study, and 101 met the criteria for the control group. Of the 162 eligible patients, 113 (69.8%) were males and 49 (30.2%) were females. In terms of age, 12 patients (7.4%) were between 20 and 39 years of age, 30 (18.5%) were between 40 and 59 years, and 120 (74.1%) were 60 years or older. Fifty-one patients (31.5%) had a surgery before their ICU admission and 111 (68.5%) did not; 75 patients (46.3%) had diabetes and 87 (53.7%) did not; and 61 patients (37.7%) had used antibiotics before catheter insertion, whereas 101 (62.3%) had no prior antibiotic exposure. A catheter was inserted in the operating room in 15 patients (9.3%), in the emergency room in 65 patients (40.1%), in general wards in 46 patients (28.4%), and in the ICU in 36 patients (22.2%). The mean duration of having an inserted catheter was 20.29 days (standard deviation [SD], 16.72), and the mean duration of an ICU stay was 18.01 days (SD, 15.32). Twenty-patients (12.3%) had a ventilator and 142 (87.7%) did not, and the mean SAPS II was 25.12 (SD, 11.04) (Table 1).

2. Clinical factors

The results of a chi-squared test and t-test to observe differences between the CAUTI and control groups are shown in Table 1. The difference in the presence of diabetes between the groups was statistically significant ($p<0.001$); it was also statistically significant ($p<0.001$) by use of a Fisher's exact test (a nonparametric test). In the CAUTI group, 65.6% of the patients had diabetes, and 34.4% did not; in the control group, 34.7% of the patients had diabetes and 65.3% did not. The difference in the durations of having an indwelling catheter and of ICU admission was statistically significant between the two groups ($p<0.01$); this difference was also shown on the Mann-Whitney test ($p<0.001$), which is a nonparametric test. The duration of having an indwelling catheter was longer in CAUTI patients (mean±SD, 27.72±20.65) than in the control group (mean±SD, 15.80±11.84), and the length of ICU admission was also longer in the CAUTI group (mean±SD, 23.08±18.77) than in the control group (mean±SD, 14.94±11.88). Other fac-

TABLE 1. Characteristics of patients and results of a chi-square test and t-test between the CAUTI and control groups

Characteristic	CAUTI (n=61)	Control (n=101)	Total	p-value
Sex				0.050 (0.055)[a]
Male	37 (60.7)	76 (75.2)	113 (69.8)	
Female	24 (39.3)	25 (24.8)	49 (30.2)	
Age (y)				0.170 (0.170)[a]
20–39	4 (6.6)	8 (7.9)	12 (7.4)	
40–59	7 (11.5)	23 (22.8)	30 (18.5)	
60+	50 (82.0)	70 (69.3)	120 (74.1)	
Previous surgery				0.943 (1.000)[a]
Yes	19 (31.1)	32 (31.7)	51 (31.5)	
No	42 (68.9)	69 (68.3)	111 (68.5)	
Diabetes				0.000[c] (0.000)[a]
Diabetic patient	40 (65.6)	35 (34.7)	75 (46.3)	
Nondiabetic patient	21 (34.4)	66 (65.3)	87 (53.7)	
Antibiotics administration				0.177 (0.185)[a]
Used	27 (44.3)	34 (55.7)	101 (62.3)	
Not used	34 (33.7)	67 (66.3)	61 (37.7)	
Place where catheter is inserted				0.784 (0.808)[a]
Operation room	4 (6.6)	11 (10.9)	15 (9.3)	
Emergency room	24 (39.3)	41 (40.6)	65 (40.1)	
General ward	19 (31.1)	27 (26.7)	46 (28.4)	
Intensive care units	14 (23.0)	22 (21.8)	36 (22.2)	
Duration of catheterization	27.72±20.65	15.80±11.84	20.29±16.72	0.000[c] (0.000)[b]
Length of ICU stay	23.08±18.77	14.94±11.88	18.01±15.32	0.001[c] (0.000)[b]
Presence of ventilator				0.794 (1.000)[a]
Yes	7 (11.5)	13 (12.9)	20 (12.3)	
No	54 (88.5)	88 (87.1)	142 (87.7)	
SAPS II	25.34±10.8	24.98±11.23	25.12±11.04	0.840 (0.830)[b]

Values are presented as number (%) or mean±standard deviation.
CAUTI, catheter-associated urinary tract infection; ICU, intensive care unit; SAPS II, Simplified Acute Physiology Score II.
[a]:Fisher's exact test. [b]:Mann-Whitney test. [c]:$p<0.001$.

tors (i.e., sex, age, recent surgery, use of antibiotics, location of catheter insertion, presence of ventilator, and SAPS II) were not significantly different between the groups ($p>0.05$).

The results of univariate and multivariate logistic regression of the factors contributing to CAUTI occurrence (i.e., sex, age, recent surgery, presence of diabetes, use of antibiotics, location of catheter insertion, duration of indwelling catheter, duration of ICU stay, presence of ventilator, and SAPS II) are shown in Table 2. In the univariate logistic regression analysis, those with diabetes were 3.59 (95% confidence interval [CI], 1.84 to 7.01; $p<0.001$) times as likely to have occurrences of CAUTI, with a 1.05-fold (95% CI, 1.03-1.08; $p<0.001$) higher incidence of increased duration of catheter placement and a 1.04-fold (95% CI, 1.01 to 1.07; $p<0.01$) longer duration of an indwelling catheter in the ICU. Other factors did not appear to have a significant effect. Thus, among the patients with CAUTI, the presence of diabetes, the duration of the indwelling catheter, and the duration of the indwelling catheter in the ICU were identified as having significant effects on CAUTI occurrence.

Using multivariate logistic regression analysis, those with diabetes were 4.55 (95% CI, 2.00 to 10.31; $p<0.001$) times as likely to have occurrences of CAUTI than were those without diabetes and also had a 1.10-fold (95% CI, 1.03 to 1.16; $p<0.01$) longer duration of an indwelling catheter. Other factors did not have significant effects on the incidence of CAUTI.

3. Microbiological factors

In the urine culture results, among the 61 patients with CAUTI, *Escherichia coli* was the most common bacterium grown; it was identified in 24 patients (38.7%), followed by *Enterococcus* spp. in 19 patients (30.6%), *Staphylococcus aureus* in 7 patients (12.9%), *Candida* spp. in 6 patients (9.7%), *Pseudomonas aeruginosa* in 3 patients (4.8%), and *Klebsiella pneumoniae* in 2 patients (3.2%) (Table 3). All patients had growth of a single strain. Six patients had evidence of the growth of extended-spectrum beta lactamase-producing *E. coli* and two patients had extended-spectrum beta lactamase-producing *Klebsiella*. Antibiotic sensitivities of the bacteria are shown in Table 4.

DISCUSSION

Although a number of studies have been performed regard-

TABLE 2. Results of univariate and multivariate analysis of factors contributing to CAUTI occurrence

	Univariate		Multivariate	
	OR (95% CI)	p-value	OR (95% CI)	p-value
Sex				
Female	1.97 (1.00–3.91)	0.052	2.17 (0.96–4.93)	0.063
Male	1.00 (referent)		1.00 (referent)	
Age (y)				
40–59	0.61 (0.14–2.64)	0.508	0.33 (0.05–2.15)	0.245
60+	1.43 (0.41–5.01)	0.577	0.91 (0.18–4.57)	0.904
20–39	1.00 (referent)		1.00 (referent)	
Previous surgery				
Yes	0.98 (0.49–1.94)	0.943	1.84 (0.67–5.09)	0.239
No	1.00 (referent)		1.00 (referent)	
Diabetes				
Diabetic patient	3.59 (1.84–7.01)	0.000[c]	4.55 (2.00–10.31)	0.000[c]
Nondiabetic patient	1.00 (referent)		1.00 (referent)	
Antibiotics administration				
Used	0.64 (0.33–1.23)	0.178	0.65 (0.27–1.59)	0.345
Not used	1.00 (referent)		1.00 (referent)	
Place where catheter is inserted				
Operation room	0.57 (0.15–2.15)	0.408	0.12 (0.02–0.80)	0.028[a]
Emergency room	0.92 (0.40–2.13)	0.845	0.34 (0.11–1.05)	0.062
General ward	1.11 (0.45–2.70)	0.825	0.32 (0.09–1.09)	0.069
ICUs	1.00 (referent)		1.00 (referent)	
Duration of catheterization	1.05 (1.03–1.08)	0.000[c]	1.10 (1.03 –1.16)	0.004[b]
Length of ICU stay	1.04 (1.01–1.07)	0.003[b]	0.97 (0.91–1.04)	0.400
Presence of ventilator		0.794		0.979
Yes	0.88 (0.33–2.34)		0.98 (0.28–3.44)	
No	1.00 (referent)		1.00 (referent)	
SAPS II	1.00 (0.98–1.03)	0.838	0.99 (0.96–1.03)	0.660

CAUTI, catheter-associated urinary tract infection; OR, odds ratio; CI, confidence interval; ICU, intensive care unit; SAPS II, Simplified Acute Physiology Score II.
[a]:$p<0.05$. [b]:$p<0.01$. [c]:$p<0.001$.

TABLE 3. Etiology of CAUTIs in ICUs

Pathogen	No. of isolated (n=61)	Remarks
Escherichia coli	24 (38.7)	6/24 (25), ESBL producers
Enterococcus spp	19 (30.6)	
Staphylococcus aureus	7 (12.9)	
Candida spp	6 (9.7)	
Pseudomonas aeruginosa	3 (4.8)	
Klebsiella pneumonia	2 (3.2)	2/2 (100), ESBL producers

Values are presented as number (%).
CAUTI, catheter-associated urinary tract infection; ICU, intensive care unit; ESBL, extended spectrum beta-lactamase.

ing the prevention of CAUTI, most used the definition of CAUTI developed by the Centers for Disease Control of the National Healthcare Safety Network (CDC-NHSN), which includes ASB. However, approximately 75% to 90% of patients with ASB do not develop a systemic inflammatory response or other signs or symptoms that suggest infection [6,7]. Additionally, the monitoring and treatment of ASB is not an effective prevention measure for symptomatic UTI (SUTI), because most cases of SUTI are not preceded by bacteriuria for more than a day [8]. ASB treatment has not been shown to be clinically beneficial and is associated with the selection of antimicrobial-resistant organisms. This study only defined symptomatic UTIs requiring treatment as CAUTI; those uninfected before ICU admission who developed CAUTI within 48 hours of transfer to the ICU were designated as CAUTI occurring in the ICU during patient selection. The CDC definition of nosocomial infection was used as a reference in developing these definitions [9-11]. Because the usual symptoms of UTI (e.g., dysuria, frequent urination, and urgency) are difficult to assess in CAUTI, the presence of fever during urine culture was used to determine SUTI.

Despite a marked reduction in the risk of bacteriuria since the introduction of the sterile, closed urinary drainage system in 1960 [12], bacteriuria inevitably occurs over time either via breaks in the sterile system or via the extraluminal route [13]. Microbial pathogens can enter the urinary tract either by the extraluminal route, via migration

TABLE 4. Antibiotic sensitivities of the gram-stained organisms

Organism	Drug susceptibility (%)													
	AC	CL	CZ	CT	GM	AK	TM	LF	IP	BT	TZ	TC	TP	VM
Escherichia coli	16.7	33.3	41.7	83.3	75	100	75	25	100	50	91.7			
Klebsiella	0	0	0	0	0	0	0	0	0	0	0			
Pseudomonas			100	33.3	33.3	33.3	33.3	33.3	33.3	33.3	100			
Enterococcus	15.8							10.5				89.5	78.9	78.9

AC, ampicillin; CL, cephalothin; CZ, ceftazidime; CT, cefotaxime; GM, gentamicin; AK, amikacin; TM, tobramycin; LF, levofloxacin; IP, imipenem; BT, bactrim; TZ, tazocin; TC, tetracycline; TP, teicoplanin; VM, vancomycin.

along the outside of the catheter in the periurethral mucous sheath, or by the intraluminal route via movement along the internal lumen of the catheter from a contaminated collection bag or catheter-drainage tube junction. The formation of biofilms by urinary pathogens on the surface of the catheter and drainage system occurs universally with prolonged durations of catheterization [14]. Over time, the urinary catheter becomes colonized with microorganisms living in a sessile state within the biofilm, rendering them resistant to antimicrobials and host defenses and virtually impossible to eradicate without removing the catheter.

Not only does the urinary catheter invite biofilm formation, but the presence of the catheter itself impairs many of the normal defense mechanisms of the bladder. The urinary catheter connects the heavily colonized perineum with the normally sterile bladder, and it provides a route for bacterial entry along both its external and internal surfaces [15]. Urine often pools in the bladder or in the catheter itself, and urinary stasis encourages bacterial multiplication [16]. Obstruction of the catheter can lead to overdistension and ischemic damage of the bladder mucosa, thus increasing its susceptibility to bacterial invasion [17]. The catheter also damages the bladder mucosa by triggering an inflammatory response and by mechanical erosion [18,19].

Several risk factors have been cited to be associated with CAUTI. In this study, only two risk factors (duration of catheterization and diabetes) were found to be significantly associated with acquisition of infection.

Increased duration of catheterization was identified as a significant factor associated with acquiring CAUTI in this study and in several other studies [1,20,21]. The occurrence of bacteriuria is inevitable while the urinary catheter is in place [13]. In prospective studies by Garibaldi et al. [8] and Warren et al. [22], the daily risk of bacteriuria with catheterization ranged from 3% to 10% and approached 100% after 30 days, which is considered to be the delineation between short- and long-term catheterization. Of course, in most cases, it was just catheter-associated ASB, which is different from CAUTI. The relationship between catheter-associated ASB and CAUTI is unclear, but the presence of catheter-associated ASB is necessary for the development of CAUTI. The development of urinary symptoms must require some facilitating events, and as the duration of catheterization is increased, the possibility of events occurring is increased also. In addition, catheter-associated ASB represents a large reservoir of antimicrobial-resistant urinary pathogens that may be transmitted to other patients and frequently triggers inappropriate antimicrobial use. Therefore, the greatest impact of an intervention may be to reduce the frequent occurrence of ASB, and the reduction of inappropriate urinary catheter durations is important for that. According to the guidelines on Diagnosis, Prevention, and Treatment of CAUTI in Adults by the Infectious Diseases Society of America in 2009, indications for urinary catheter insertion are described as follows: clinically significant urinary retention, urinary incontinence, accurate urine output monitoring required, and patient unable or unwilling to collect urine [23].

This study identified diabetes as a factor in the development of CAUTI, and diabetes as a factor in the development of UTIs has been confirmed in numerous other studies. Geerlings and Hoepelman [24] noted that in patients with diabetes, impaired granulocyte function, increased adherence of uropathogens to bladder epithelial cells, and the effects of glucosuria on the growth of uropathogens in diabetic patients contribute to a higher UTI prevalence. Platt et al. also documented the presence of diabetes as a risk factor and proposed two possibilities for why diabetic patients are at increased risk of acquiring infection: an increased prevalence of perineal colonization by potential pathogens and an increased ability of the urine of some patients with diabetes to support microbial growth [20]. These effects of diabetes promote the colonization of uropathogens on the catheter surface when urinary catheters are indwelled and affect the synthesis of biofilms. In addition, the immunocompromised state, which is a characteristic of these patients, allows bacteriuria to easily extend into the upper urinary tract. Patients with diabetes, especially those admitted to the ICU with indwelling catheters, are more susceptible to the development of urosepsis; thus, these patients require strict blood glucose monitoring to prevent CAUTI occurrence and progression.

According to the 2006 to 2007 statistics from the NHSN, the pathogens identified (in the order of frequency) were *E. coli* (21.4%), *Candida* spp. (21.0%), *Enterococcus* spp. (14.9%), *P. aeruginosa* (10.0%), *K. pneumoniae* (7.7%), and

Enterobacter spp. (4.1%); this grouping is similar to the culture results from this study. However, this study had a smaller proportion of *Candida* spp. compared with the NHSN numbers, which is thought to be attributable to the fact that the NHSN study did not distinguish between SUTI and ASB, whereas this study specifically selected those with SUTI.

In the other studies, the risk factors associated with CAUTI included the duration of catheterization, diabetes mellitus, not receiving systemic antimicrobial therapy, female sex, catheter insertion outside the operating room, and older age [14,20,25-29]. The different outcomes in present study may be because we distinguished between SUTI and ASB but could also be due to the limitations of this study.

A limitation of this study is that it included a relatively small number of patients in both the CAUTI and control groups, because it was a retrospective analysis that was conducted on the basis of data from a single hospital. Consequently, to complement this fact, a prospective analysis based on data from multiple institutions is necessary. The results from such studies will aid in the development of guidelines for the prevention of CAUTI in ICUs that are appropriate for Korean hospital settings.

CONCLUSIONS

Among the patients with CAUTI, the presence of diabetes and the duration of catheter placement were identified as factors having significant effects on CAUTI occurrence. In the results of the urine culture, *E. coli* was the most common bacterium grown among the patients with CAUTI. The factors and causative organisms contributing to the development of CAUTI in the management of ICU patients must be considered to prevent the occurrence of UTIs in this setting.

CONFLICTS OF INTEREST

The authors have nothing to disclose.

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