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Original Article

Risk factors for urinary tract infection and asymptomatic bacteriuria after stroke

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Abstract

Introduction: Urinary tract infections occur in approximately 19% of stroke patients. Urinary tract infections are proven to adversely affect the short-term and long-term outcomes of stroke, prolong hospitalization, and increase treatment costs. This study aimed to determine the risk factors for the occurrence of urinary tract infection and asymptomatic bacteriuria.

Methodology: This retrospective case-control study was conducted in the neurological intensive care unit, in a tertiary healthcare facility, from July 2018 to July 2022.

Results: Our study demonstrated that older patients with worse neurological status upon admission, were at a higher risk for the occurrence of urinary tract infection. This factor also predisposed the occurrence of asymptomatic bacteriuria. The patients who received ceftriaxone and fluoroquinolone were at a lower risk of developing a urinary tract infection, while carbapenem and vancomycin administration could potentiate the occurrence of a urinary tract infection.

Conclusions: Based on these results, we can identify the patients who are at a higher risk of developing a urinary tract infection and take measures to prevent infection, such as decreasing the duration of catheterization or replacing the urinary catheter more frequently. The results also enable us to identify the patients who are at a higher risk of developing asymptomatic bacteriuria.

Key words: urinary tract infection; UTI; asymptomatic bacteriuria; stroke.

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Introduction

Stroke is one of the leading causes of death and disability, and therefore it presents as a serious healthcare concern [1]. A large number of patients who have a stroke require hospitalization in the neurological intensive care unit (ICU), to receive possible treatments such as thrombolysis and thrombectomy [2]. The serious condition of these patients with a long and uncertain recovery requires prolonged hospitalization, which carries a risk of nosocomial infections [3]. Urinary tract infection (UTI) and pneumonia are the most commonly occurring infections after a stroke [3]. UTI occurs in approximately 19% of patients who had a stroke [4]. Its well-known risk factors include the presence and duration of urinary catheterization [5,6]. However, urinary catheterization is often necessary in patients who are being treated after a stroke. UTIs are proven to adversely affect the short-term and long-term outcomes of stroke, prolong hospitalization, and increase treatment costs [7]. UTI is defined by the presence of symptoms or signs related to the urinary tract, and associated with the presence of 10^5 cfu/mL of $\geq$ 1 bacterial species in a single urine specimen [8]. Fever or other systemic symptoms may be the only clinical indication of UTI in patients who are critically ill, such as patients with stroke, or who have spinal cord injuries [8]. Most UTIs in stroke patients are categorized as complicated, due to the presence of catheters [9]. The occurrence of UTI leads to antibiotic administration, which exposes the patient to potential side effects of the antibiotic and its interactions with other drugs. It also contributes to the development of antibiotic-resistant bacteria and additionally increases the treatment costs [10]. Thus, using antibiotics only in cases where they are required is crucial. An example of unsubstantiated use of antibiotics is asymptomatic bacteriuria (ASB), which is frequently observed in patients with a urinary catheter [11,12]. ASB is identified when voided urine specimens have at least 10^5 cfu/mL of a uropathogen isolated in the absence of signs or symptoms of urinary infection [11]. Differentiating ASB from UTI can be very difficult, particularly in patients presenting with non-specific symptoms [13]. Strategies for preventing UTIs exist

and have been proven efficient. These include measures such as shortening the duration of urinary catheterization and utilization of special types of catheters [14].

This study aimed to determine the risk factors for UTI occurrence to ensure that preventive measures are implemented or early treatment of infection in high-risk patients is performed. Furthermore, we aimed to distinguish patients who were at a higher risk of ASB, so as to consider its possibility before introducing potentially unnecessary antibiotic therapy.

Methodology

An observational, retrospective case-control study was conducted in the neurological ICU, in a tertiary healthcare facility, from July 2018 to July 2022. This study included patients of both genders, aged ≥18 years, diagnosed with an ischemic or hemorrhagic stroke based on neurological examination, had computed tomography or magnetic resonance imaging findings of the endocranium, and had an inserted urinary catheter. The exclusion criteria were hospitalization shorter than 48 hours, UTI that was diagnosed within < 48 hours after admission, immunocompromised patients, patients aged < 18 years, and pregnant women. The case group included patients with a stroke and inserted urinary catheter who developed UTI or ASB, whereas the control group included patients with a stroke and inserted urinary catheter who did not have UTI nor ASB.

Statistics

The data were first entered into a Microsoft Office Excel 2019 spreadsheet and then transferred to a spreadsheet of the Statistical Software for Social Sciences (SPSS) for Windows (version 18.0, SPSS Inc., Chicago, Illinois, USA). After checking the accuracy of the input and analyzing the extreme values of the study variables, error corrections were made, and the database was prepared for further statistical processing.

The Chi square test was used to compare the difference between the study groups in the case of categorical variables. The Fisher's exact test was used if the frequency of one of the categories of the variables being compared was less than 5. One-way analysis of variance was used to compare the values of continuous variables between the study groups if the data distribution was normal, and Kruskal-Wallis non-parametric analysis of variance was used in the case where the data were not normally distributed.

The multinomial logistic regression analysis was used to examine the simultaneous influence of independent and confounding variables (predictors) on categorical outcomes with more than two categories. The final model was obtained by backward deletion procedure. The quality of the final model was examined with the likelihood ratio test, and with the Pearson Chi square test. The extent to which the final multinomial logistic regression model explained outcome variability was assessed by calculating Nagelkerke's pseudo R^2 and Cox & Snellen's pseudo R^2. The results of all statistical tests were considered statistically significant if the probability of the null hypothesis was below 0.05.

Results

There were 100 patients with stroke and ASB, 100 patients with stroke and UTI, and 100 patients with stroke and without ASB or UTI. The age of the patients (71.4 ± 11.2, 74.5 ± 8.2, and 72.5 ± 9.4 years, respectively), and the distribution of genders (male/female 43.0%/57.0%, 52.0%/48.0%, and 51.0%/49.0%, respectively) in these three groups were not significantly different. Distribution of other characteristics of the three study groups, and significance of differences among them are summarized in the Table 1. The patients with UTI were hospitalized for longer duration than patients with ASB and control patients; and the duration of bladder catheterization was also the longest in the UTI group. The patients without ASB and UTI were more often prescribed levofloxacin or ceftriaxone, while vancomycin and ertapenem were more frequently prescribed to patients with ASB or UTI. The patients with atrial fibrillation were more frequent in the group without ASB or UTI.

When the outcome (ASB and UTI) was considered as the degree of bacterial invasion of urinary tract (no invasion, ASB, and UTI), the influence of age, gender, antibiotic therapy, comorbidities, duration of hospitalization, etc., was examined by multinomial logistic regression. The obtained regression model was significant, because the likelihood ratio test for the final model was: Chi square = 91.274, df = 46, p = 0.000. Nagelkerke pseudo R^2 was 0.370, and Cox & Snellen R^2 was 0.338, which means that the model explained as much as 37.0% and 33.8% of the outcome variability; i.e., degree of bacterial invasion of the urinary tract. Analysis of the coefficients of variables with significant influence indicated that: (1) each point of the Glasgow Coma Scale (GCS) on admission increased the chances of ASB by 1.35 times; (2) each point of the National Institutes of Health Stroke Scale (NIHSS) on admission increased the chances of ASB 1.21 times; (3) absence of atrial fibrillation increased the chances of ASB 4.54 times; (4) administration of ceftriaxone decreased the

Table 1. Characteristics of respondents according to study groups.

Variables	Control (n = 100)	Patients with UTI (n = 100)	Patients with asymptomatic bacteriuria (n = 100)	Probability of null hypothesis (*p*)
Age (years)	72.5 ± 9.4, 72.0 [14.0]	74.5 ± 8.2, 75.0 [12.0]	71.4 ± 11.2, 72.0 [15.0]	0.156
Length of hospitalization (days)	11.4 ± 5.8, 10.0 [7.0]	18.5 ± 8.0, 18.0 [11.0]	15.2 ± 6.0, 14.0 [7.0]	0.000
Urea (mmol/L)	7.7 ± 5.0, 6.8 [3.0]	8.8 ± 6.3, 7.0 [3.8]	6.8 ± 3.0, 5.8 [3.4]	0.023
Creatinine (μmol/L)	96.3 ± 55.7, 81.5 [28.0]	109.3 ± 73.5, 91.0 [35.0]	95.3 ± 71.0, 76.5 [27.0]	0.010
Glycemia (mmol/L)	8.6 ± 9.5, 7.3 [2.8]	8.2 ± 4.3, 7.0 [3.3]	7.9 ± 3.7, 7.0 [2.7]	0.908
Hematocrit	0.40 ± 0.05, 0.41 [0.07]	0.40 ± 0.06, 0.40 [0.07]	0.39 ± 0.06, 0.40 [0.07]	0.074
D-dimer	2.0 ± 3.2, 0.8 [1.7]	2.4 ± 2.6, 1.8 [1.7]	4.0 ± 5.6, 1.5 [4.7]	0.063
Potassium (mmol/L)	4.1 ± 0.8, 4.0 [0.7]	4.1 ± 0.5, 4.1 [0.6]	3.9 ± 0.4, 3.9 [0.4]	0.033
Sodium (mmol/L)	135.4 ± 19.4, 138.0 [4.0]	138.4 ± 5.1, 138.0 [6.0]	138.4 ± 5.0, 139.0 [4.0]	0.795
GCS* on admission	13.0 ± 2.2, 14.0 [4.0]	12.8 ± 2.2, 13.0 [4.0]	13.0 ± 1.9, 14.0 [2.0]	0.830
NIHSS* on admission	6.4 ± 3.2, 6.0 [4.0]	7.4 ± 3.6, 7.0 [6.0]	7.0 ± 3.5, 7.0 [5.0]	0.153
Length of urinary bladder catheterization (days)	11.1 ± 5.8, 10.0 [7.0]	18.4 ± 7.9, 18.0 [11.0]	15.3 ± 6.0, 14.0 [7.0]	0.000
The day of hospitalization when the infection was diagnosed	-	10.1 ± 6.7, 7.5 [9.0]	-	
Day of hospitalization when asymptomatic bacteriuria was diagnosed	-	-	7.4 ± 3.4, 6.5 [4.0]	
CRP when taking urine culture (mg/L)	-	147.8 ± 83.4, 122.4 [107.9]	-	
Leukocytes when taking urine culture ($x10^9$/L)	-	11.4 ± 4.5, 10.6 [5.0]	-	
Gender (M/F)	51/49 (51.0%/49.0%)	52/48 (52.0%/48.0%)	43/57 (43.0%/57.0%)	0.378
DM* (yes/no)	27/73 (27.0%/73.0%)	29/71 (29.0%/71.0%)	33/67 (33.0%/67.0%)	0.639
Second stroke (yes/no)	7/93 (7.0%/93.0%)	6/94 (6.0%/94.0%)	5/94 (5.1%/94.9%)	0.953
Chronic renal failure (yes/no)	3/97 (3.0%/97.0%)	5/95 (5.0%/95.0%)	5/95 (5.0%/95.0%)	0.823
Benign prostatic Hyperplasia (yes/no)	1/99 (1.0%/99.0%)	2/98 (2.0%/98.0%)	1/99 (1.0%/99.0%)	1,000
Atrial fibrillation (yes/no)	29/71 (29.0%/71.0%)	24/76 (24.0%/76.0%)	15/85 (15.0%/85.0%)	0.057
Origin of a patient (home/other ward)	92/8 (92.0%/8.0%)	93/7 (93.0%/7.0%)	91/9 (91.0%/9.0%)	0.873
Previous hospitalization within 90 days from the current one (yes/no)	10/90 (10.0%/90.0%)	18/82 (18.0%/82.0%)	12/88 (12.0%/88.0%)	0.223
Previous hospitalization in intensive care unit within 90 days from the current one (yes/no)	7/93 (7.0%/93.0%)	10/90 (10.0%/90.0%)	6/94 (6.0%/94.0%)	0.542
Antibiotic therapy within 90 days before admission (yes/no)	4/96 (4.0%/96.0%)	12/88 (12.0%/88.0%)	10/90 (10.0%/90.0%)	0.111
COVID-19 within 6 months before admission (yes/no)	4/96 (4.0%/96.0%)	3/97 (3.0%/97.0%)	5/95 (5.0%/95.0%)	0.932
COVID-19 during current hospitalization (yes/no)	0/4 (0.0%/100.0%)	3/0 (100.0%/0.0%)	2/3 (40.0%/60.0%)	0.032
Conscious on admission (yes/no)	70/30 (70.0%/30.0%)	60/39 (60.6%/39.4%)	74/26 (74.0%/26.0%)	0.114
Isolated from urine: *Proteus* spp/*Proteus mirabilis*/*Enterococcus*/*Escherichia coli*/*Klebsiella* spp/*Klebsiella pneumoniae*/*Enterobacter*/*Acinetobacter*/*Proteus vulgaris* / *Pseudomonas*/*Providence*/other		1/9/18/9/36/1/3/6/3/8/3/3 (1.0%/9.0%/18.0%/9.0%/36.0%/1.0%/3.0%/6.0%/3.0%/8.0%/3.0%/3.0%)	5/10/24/16/20/2/1/1/2/7/8/4 (5.0%/10.0%/24.0%/16.0%/20.0%/2.0%/1.0%/1.0%/2.0%/7.0%/8.0%/4.0%)	0.078
Antibiotic therapy (yes/no)	35/65 (35.0%/65.0%)	94/5 (94.9%/5.1%)	76/24 (76.0%/24.0%)	0,000
Outcome (discharge/ transfer/ death)	78/3/19 (78.0%/3.0%/19.0%)	77/4/17 (78.6%/4.1%/17.3%)	82/11/7 (82.0%/11.0%/7.0%)	0.016
Cephalexin (yes/no)	3/62 (4.6%/95.4%)	8/92 (8.0%/92.0%)	3/97 (3.0%/97.0%)	0.324
Cefazolin (yes/no)	6/59 (9.2%/90.8%)	12/88 (12.0%/88.0%)	7/93 (7.0%/93.0%)	0.480
Ceftriaxone (yes/no)	26/39 (40.0%/60.0%)	46/54 (46.0%/54.0%)	36/64 (36.0%/64.0%)	0.010
Cefepime (yes/no)	8/57 (12.3%/87.7%)	15/85 (15.0%/85.0%)	11/89 (11.0%/89.0%)	0.692
Levofloxacin (yes/no)	18/47 (27.7%/72.3%)	20/80 (20.0%/80.0%)	7/93 (7.0%/93.0%)	0.002
Ceftazidime (yes/no)	3/62 (4.6%/95.4%)	5/95 (5.0%/95.0%)	5/95 (5.0%/95.0%)	1.000
Piperacilin-tazobactam (yes/no)	2/63 (3.1%/96.9%)	10/90 (10.0%/90.0%)	4/96 (4.0%/96.0%)	0.137
Meropenem (yes/no)	6/59 (9.2%/90.8%)	18/82 (18.0%/82.0%)	12/88 (12.0%/88.0%)	0.232
Colistin (yes/no)	3/62 (4.6%/95.4%)	11/89 (11.0%/89.0%)	2/98 (2.0%/98.0%)	0.030
Moxifloxacin (yes/no)	1/63 (1.6%/98.4%)	2/98 (2.0%/98.0%)	3/95 (3.1%/96.9%)	0.884
Ciprofloxacin (yes/no)	1/64 (1.5%/98.5%)	7/93 (7.0%/93.0%)	6/94 (6.0%/94.0%)	0.267
Vancomycin (yes/no)	5/60 (7.7%/92.3%)	19/81 (19.0%/81.0%)	14/86 (14.0%/86.0%)	0.134
Metronidazole (yes/no)	1/64 (1.5%/98.5%)	4/96 (4.0%/96.0%)	4/96 (4.0%/96.0%)	0.756
Cefixime (yes/no)	1/63 (1.6%/98.4%)	7/93 (7.0%/93.0%)	2/97 (2.0%/98.0%)	0.189
Amikacin (yes/no)	8/57 (12.3%/87.7%)	27/73 (27.0%/73.0%)	25/75 (25.0%/75.0%)	0.068
Gentamycin (yes/no)	2/63 (3.1%/96.9%)	7/93 (7.0%/93.0%)	3/97 (3.0%/97.0%)	0.422
Ertapenem (yes/no)	6/59 (9.2%/90.8%)	22/78 (22.0%/78.0%)	10/90 (10.0%/90.0%)	0.021
Azithromycin (yes/no)	5/60 (7.7%/92.3%)	4/96 (4.0%/96.0%)	4/96 (4.0%/96.0%)	0.484
Low-molecular-weight heparin(yes/no)	84/16 (84.0%/16.0%)	83/17 (83.0%/17.0%)	77/23 (77.0%/23.0%)	0.740

Continuous variables are presented as mean ± standard deviation (SD), median, and [interquartile range]. Categorical variables are presented as frequencies and percentages. The differences in continuous variables between the study groups were tested by Kruskal-Wallis nonparametric analysis of variance, and posthoc pairwise comparisons; and the differences in categorical variables by Chi square test or Fisher's exact test, where appropriate. COVID-19: coronavirus diease 2019; CRP: C reactive protein; DM: diabetes mellitus; GCS: Glasgow coma scale; NIHSS: National Institutes of Health Stroke Scale; UTI: urinary tract infection.

chances of ASB 3.16 times, and that of UTI 2.52 times; (5) age increased the chances of UTI, since each year of age increased the chances by 1.06 times; and (6) administration of vancomycin increased the chances of UTI about 5 times. The results are summarized in Table 2.

Discussion

This study revealed that old age is a significant factor in increasing the chances of developing UTI in patients with a stroke and an inserted urinary catheter. This is because changes in the anatomical and physiological characteristics of the urinary tract occur over the years. As a result, the anatomical barrier has decreased efficiency, and the pathogen adhesion to the urinary bladder wall increases [15]. Notable factors such as specific metabolic disorders (that are more common at an older age), changes in the urine pH, and changes in urine glucose level that are more common in older patients increase the risk of developing UTI [15]. Additionally, a certain level of immunosuppression present in older patients makes this group of patients more susceptible to infections [16].

The results of our study revealed a significant difference among patients based on which antibiotic was used in their treatment. The results revealed that patients, who received vancomycin and ertapenem had more frequent urinary infections than those who received ceftriaxone or levofloxacin. These results can be considered from different perspectives. First, the positive outcome of ceftriaxone and levofloxacin administration confirms that these two drugs are a good choice for treating complicated UTIs, as well as UTIs that occur after a urinary catheter is inserted [9,17]. Second, the analysis of results which indicate that ertapenem and vancomycin administration increases the chances of getting a UTI, is complex. This result is in contradiction to the familiar observation that ertapenem represents a good choice for treating complicated UTIs [17]. However, when we consider the results of this study, which revealed that the most common etiological agents for UTI were *Klebsiella* spp., *Enterococcus*, and *Escherichia coli*, we conclude that the presence of antibiotic resistance was the reason for increase in chances of UTI following administration of ertapenem and vancomycin. Carbapenem resistance represents a considerable problem with increasing number of cases, especially in the last decade [18,19]. Gram-negative bacteria that are resistant to carbapenems, also known as carbapenem-resistant *Enterobacteriaceae,* play a significant role in causing UTIs [20]. The most important pathogens among them are *Klebsiella pneumoniae* and *E. coli* [21]. These infections can be efficiently treated by aminoglycosides, tigecycline, ceftazidime-avibactam, and imipenem–cilastatin–relebactam [19,21]. Levofloxacin and ciprofloxacin are also efficient to a certain extent [21].

The use of antibiotics in patients should be justified by diagnosis of a bacterial infection. However, due to lack of formal antibiotic stewardship in the hospital where the study was done, it is possible that at least some of the cases of prescribing antibiotics were not justified, thus creating conditions for selection of resistant and more pathogenic strains of bacteria that could later on cause UTI or ASB in greater numbers. The results of our study should encourage the hospital management to establish and maintain a stable antimicrobial stewardship program.

Vancomycin resistance also represents a substantial problem in terms of antibiotic resistance. The most important example of this type of resistance are infections that are caused by vancomycin-resistant *Enterococcus* [22]. *Enterococcus* is well-known as one of the three most common causes of UTIs, especially intrahospital infections. An estimated 15% of all UTIs associated with urinary catheter insertion are caused by bacteria belonging to genus *Enterococcus* [23]. Ampicillin is a good choice in treating infections that are caused by vancomycin-resistant *Enterococcus* [23]. Levofloxacin and ciprofloxacin are recommended only in cases of uncomplicated cystitis caused by vancomycin-resistant *Enterococcus* [24].

Table 2. Putative predictors of urinary tract infection and/or asymptomatic bacteriuria – coefficients of multinomial logistic regression.

Factor	Crude OR (± 95% CI*)	*p* value	Adjusted OR (± 95% CI)	*p* value
Asymptomatic bacteriuria				
GCS on admission	1.014 (0.887 – 1.159)	0.838	1.355 (1.047 – 1.753)	0.021
NIHSS on admission	1.059 (0.977 – 1.149)	0.163	1.210 (1.030 – 1.422)	0.020
Absence of atrial fibrillation	2.315 (1.151 – 4.654)	0.019	4.538 (1.658 – 12.418)	0.003
Avoiding ceftriaxone prescribing	2.667 (1.402 – 5.071)	0.003	3.162 (1.378 – 7.257)	0.007
Urinary tract infection				
Age	1.023 (0.991 – 1.055)	0.156	1.060 (1.009 – 1.114)	0.021
Avoiding ceftriaksone prescribing	1.761 (0.935 – 3.317)	0.080	2.523 (1.105 – 5.763)	0.028
Avoiding vancomycin prescribing	0.355 (0.126 – 1.005)	0.051	0.202 (0.042 – 0.963)	0.045

CI: confidence interval; GCS: Glasgow coma scale; NIHSS: National Institutes of Health Stroke Scale; OR: odds ratio.

ASB is frequently responsible for unsubstantiated use of antibiotics and it becomes a factor that contributes to antibiotic resistance [25]. Our results revealed that patients with higher NIHSS and GCS scores are at a higher risk of developing ASB. Evaluating the consciousness condition, speech function, and motor system function is common for both scales; and this helped us conclude that a higher score on both scales demonstrated that we were dealing with a larger infarction zone that affected the more important brain centers [26]. Certain studies demonstrated a connection between the size of the infarction zone and degree of consequential immunosuppression. The infarct volume affects the degree of lymphopenia and monocyte dysfunction, thereby affecting the susceptibility of an organism to infection [27,28].

Studies have revealed that the conditions of immunosuppression predispose the occurrence of ASB, which can explain our results [29,30]. The results of our study, which are significant, indicated that patients with atrial fibrillation were at a lower risk of developing ASB. We were obligated to administer the therapy doses of low-molecular-weight heparin (LWMH) in patients with atrial fibrillation, to prevent the occurrence of thrombosis, which is a considerable risk for these patients [31,32]. However, certain antimicrobial properties of heparin have been reported earlier. These studies were conducted to develop alternative treatments for recurrent UTIs because the standard practice of chronic use of small doses of antibiotics in the prevention of recurrent UTIs contributed to increased antibiotic resistance [33]. Certain layer damage in the transitional epithelium of the bladder, specifically in the glycosaminoglycan layer, enables bacteria to easily adhere to the bladder epithelium, which affects the development of a UTI [34]. The potential of different substances to prevent adherence of microorganisms has also been examined. Among them, heparin was tested because it is a glycosaminoglycan that has an anti-adherent property due to its negative charge. Heparin was instilled in the urinary bladder through a catheter in doses 25,000–50,000 IU, usually in combination with lidocaine and sodium bicarbonate. Such intravesical use suppressed recurrent UTIs [33,35,36]. LWMH, which we administered in higher doses to patients with atrial fibrillation, is dominantly eliminated through kidneys. Therefore, our results indicate that its efficacy is achieved at the urinary tract level even in cases of parenteral administration of heparin.

Conclusions

There are three main conclusions of our study: (1) advanced age patients with worse neurological status upon admission were at a higher risk of developing UTI or ASB; (2) the patients treated with ceftriaxone or a fluoroquinolone were at lower risk of acquiring an UTI, while carbapenem and vancomycin administration increased the risk of UTI; and (3) the patients treated with higher doses of low-molecular weight heparins were less likely to develop ASB. Based on these conclusions, we can identify the patients who are at a higher risk of developing an UTI and take measures to prevent infection, such as decreasing the catheterization duration or replacing the urinary catheter more frequently. Regular screening for UTI as well as eventual early administration of antibiotics with adequate drug selection is beneficial to these patients. However, further research is necessary to investigate many putative predictors or protective factors of UTI or ASB in stroke patients that either remained with false negative influence due to insufficient statistical power of our study, or were not captured within the scope of included study variables due to local practice variation.

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Conflict of interests

No conflict of interests is declared.

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