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Original Article

Benefits of bladder point-of-care ultrasound for acute ischemic stroke and application of AGN3 criteria

*Cheng-Lun Hsiao[a,b], Wan-Ling Chang[a], Pei-Ya Chen[a,b], Shinn-Kuang Lin[a,b]**

[a]Stroke Center and Department of Neurology, Taipei Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation, New Taipei, Taiwan, [b]School of Medicine, Tzu Chi University, Hualien, Taiwan

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Abstract

Objectives: We investigated the benefits of bladder point-of-care ultrasound (POCUS) during acute ischemic stroke (AIS) by applying AGN3 criteria. **Materials and Methods:** Three groups of inpatients with AIS were retrospectively enrolled. Group A (between January 2011 and March 2014) comprised 1104 patients who did not undergo bladder POCUS. Group B (between May 2014 and February 2017) comprised 824 patients for whom relaxed bladder POCUS criteria were applied. Group C (between July 2021 and October 2023) comprised 920 patients for whom AGN3 criteria were applied (i.e., age ≥75 years, female gender, National Institutes of Health Stroke Scale [NIHSS] total score ≥5, NIHSS conscious score ≥1, and NIHSS leg score ≥2). **Results:** The proportions of patients who met the AGN3 criteria were 76%, 73%, and 72% in Groups A, B, and C, respectively. Only 33% of Group B and 50% of Group C patients who met the AGN3 criteria underwent bladder POCUS. The incidence of urinary tract infection (UTI) was highest in Group A (6.9%), followed by Groups B (4%) and C (2.1%). The optimal cutoff postvoid residual urine volume for predicting UTI was ≥100 mL. The hospital length of stay (LOS) was longer in Group A (13.6 days) than in Groups B and C (11.9 and 12.1 days, respectively). A C-statistic of 0.814 was estimated using the AGN3 criteria. AGN3 score ≥2 was the optimal cutoff value for predicting UTI. **Conclusion:** Bladder POCUS is beneficial for reducing the incidence of UTI and shortening hospital LOS. Patients with AGN3 score ≥2 were at higher risk of UTI and required bladder POCUS studies.

Keywords: *Acute ischemic stroke, Bladder ultrasound, Length of stay, Point-of-care ultrasound, Urinary tract infection*

Introduction

Functional disabilities inhibit the performance of daily functions. Acute strokes can result in functional disabilities. Patients with impaired consciousness or lower limb paralysis have restricted mobility and are often partially or completely bedridden. Being bedridden can worsen the symptoms of physical conditions such as benign prostate hypertrophy and neurogenic bladder – two conditions that interfere with urinary function. Increases in postvoid residual urine (PVRU) volumes are associated with urinary tract infections (UTIs). UTIs are among the most common infections in patients hospitalized for stroke and are associated with longer hospital length of stay (LOS) and unfavorable functional outcomes [1,2].

PVRU volume is a key indicator for evaluating the function of the lower urinary tract system [3]. Point-of-care ultrasound (POCUS), defined as ultrasonography conducted at a bedside in real-time by a care provider, is an effective and reproducible bedside procedure for evaluating PVRU volume [4,5]. Our previous study indicated that the implementation of bladder POCUS significantly reduced the incidence of UTI and hospital LOS in patients with acute ischemic stroke (AIS) [6]. We also established a set of AGN3 criteria to identify patients suitable for bladder POCUS [6]. We adopted the AGN3 criteria as part of our hospital's medical quality and patient safety standards and integrated them into our hospital information system. Upon admission of a patient with AIS, the hospital information system automatically prompts physicians to evaluate whether the patient meets the

**Address for correspondence:* Dr. Shinn-Kuang Lin, Stroke Center and Department of Neurology, Taipei Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation, 289, Jianguo Road, Xindian District, New Taipei, Taiwan.
E-mail: sk2022@tzuchi.com.tw

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AGN3 criteria and to conduct two bladder POCUS studies on separate days within 1 week of hospitalization. To evaluate the benefits of bladder POCUS, we analyzed three groups of patients at various stages of bladder POCUS settings over 12 years.

Materials and methods

Study population and data collection

Three groups of patients with AIS were retrospectively enrolled. Groups A and B comprised the population studied in our previous study. Group A consisted of 1104 patients without bladder POCUS who were hospitalized between January 1, 2011, and April 8, 2014, and Group B consisted of 824 patients who were hospitalized between April 9, 2014, and February 28, 2017, and for whom relaxed criteria for bladder POCUS were applied (i.e., impaired consciousness and dependent ambulation) [6]. Methods for establishing the AGN3 criteria for selecting patients at risk of UTI have been reported elsewhere [6]. In September 2021, the AGN3 criteria were incorporated into our hospital information system as a standard for medical care. We conducted bladder POCUS on the basis of the AGN3 criteria and retrospectively enrolled 920 patients hospitalized between July 1, 2021, and October 31, 2023 (Group C). Patients who were initially admitted to the intensive care unit for severe stroke or who had a urinary catheter inserted in the emergency department before admission to the ward were excluded.

The following information was collected: age; sex; National Institutes of Health Stroke Scale (NIHSS) total, conscious, and leg scores; indwelling urinary catheterization necessity; PVRU volume; occurrence of UTI; and hospital LOS.

A hospital-acquired UTI was defined as symptomatic pyuria requiring antibiotic treatment in a patient who had a clear urinary analysis upon admission. Outcomes were evaluated using the NIHSS, Barthel Index, and modified Rankin Scale (mRS) at discharge. An mRS score of >2 was regarded as an unfavorable outcome.

Ethical statement

The present study was conducted in accordance with the Declaration of Helsinki. Ethical approval for the present study was granted by the Institutional Review Board of Taipei Tzu Chi Hospital, New Taipei City (approval no. 12-X-102). The requirement for informed consent was waived because the study only involved retrospective data analysis. All the collected and analyzed data were derived from clinical records without any intervention or influence on clinical treatment. To fully protect patient privacy and rights, only clinical observation data have been published; no personal information was disclosed to any third party without patient consent.

AGN3 criteria and bladder point-of-care ultrasound study

AGN3 criteria for identifying inpatients at risk of UTI after acute stroke were established in our previous study [6]. AGN3 criteria are scored using five items, each assessing the presence of a specific clinical characteristic; each item is assigned a score of 1 if the corresponding clinical characteristic is present, resulting in a total score ranging from 0 to 5. The clinical characteristics are age ≥75 years, female gender, initial total NIHSS score ≥5, initial NIHSS conscious score ≥1 (ranging from "not alert" to "coma"), and initial NIHSS leg score ≥2 (ranging from "some effort against gravity" to "flaccid"). These five items are key factors influencing the occurrence of UTI. Patients admitted to the stroke unit after AIS who met one or more of the AGN3 criteria (AGN3 score ≥1) were regarded as eligible to undergo at least two bladder POCUSs on separate days within the 1st week of hospitalization. The highest PVRU volume was used for further analysis. Bladder POCUS is currently a routine medical procedure used in the prevention of UTI in patients with AIS in our stroke unit.

Bladder POCUSs were performed by trained rotational or long-term care in-charge resident physicians and long-term care advanced-practice registered nurses. Before measurement, all ultrasound operators underwent a short-term training program, including a video detailing the procedure, to teach them how to measure the PVRU volume. The bladder POCUS scanning process was performed within 15 min after voiding in clear patients or after changing the wet-in diaper in unconscious patients. Group B was assessed using a portable SonoSite Titan ultrasound system (SonoSite, Bothell, WA, USA), and Group C was assessed using a wireless pocket-sized ASUS LU700C ultrasound scanner (ASUSTek Computer, Taipei, Taiwan) that used real-time B-mode imaging. The urinary bladder was placed in the central position of the B-mode ultrasound imaging to ensure the best insonation angle. Horizontal and vertical plane images of the bladder were obtained. The following equation was used to calculate PVRU volume: width × depth × height × 0.52 [7].

Statistical analysis

Analysis of variance was conducted to evaluate differences in the means of continuous variables. The Chi-square test was used for categorical data comparisons. Multiple logistic regression was used to analyze the factors influencing UTI risk and other outcomes. Variable predictive performance was analyzed using the C-statistic. Receiver operating characteristic (ROC) curve analysis was employed to determine the optimal cutoff values for PVRU volume and AGN3 score in predicting UTI. $P < 0.05$ was regarded as statistically significant, and all statistical analyses were performed using SPSS (version 24; IBM, Armonk, NY, USA). Scatter plot diagrams were constructed, and ROC curves were compared using MedCalc (version 18; MedCalc Software, Mariakerke, Belgium).

Results

A total of 2848 patients were enrolled. Groups A, B, and C comprised 1104, 824, and 920 patients, respectively. Given that bladder POCUS is simply a recommendation in the clinical pathway of patient care, not all patients who met the AGN3 criteria underwent bladder POCUS because of the physician's discretion or unintentional neglect. The numbers of patients in Groups A, B, and C who met the AGN3 criteria were 841 (76%), 605 (73%), and 663 (72%), respectively. Group A

did not receive bladder POCUS. In total, 31% of Group B and 40% of Group C received bladder POCUS. Among patients meeting the AGN3 criteria, 33% (202/603) in Group B and 50% (329/663) in Group C received bladder POCUS. Table 1 summarizes the clinical features and distribution of AGN3 scores for all 2848 enrolled patients. Comparisons of baseline data did not reveal any significant differences in initial NIHSS scores, proportions of patients aged ≥75 years, NIHSS total scores ≥5, NIHSS leg scores ≥2, mean AGN3 scores, or AGN3 scores ≥1 among the groups. Group C had a higher bladder POCUS rate (40%) than did Group B (31%). Group C also had a higher bladder POCUS rate (50%) among patients with an AGN3 score of ≥1 than did Group B (33%). In total, 95% of the patients who received bladder POCUS in Group C had an AGN3 score of ≥1. The proportion of patients with an indwelling urinary catheter was 8.2% in Group A, 13% in Group B, and 16% in Group C. Conversely, the incidence of UTI was 6.9% in Group A, 4.0% in Group B, and 2.1% in Group C. Hospital LOS was 13.6 days in Group A, 11.9 days in Group B, and 12.1 days in Group C. An outcome assessment revealed no significant difference among the three groups in terms of discharge NIHSS scores, Barthel Index scores, and unfavorable outcomes (mRS >2).

Given that bladder POCUS studies are recommended for an AGN3 score >0, it does not seem appropriate to compare the incidence of UTI between patients who did and did not undergo POCUS among all patients in each patient group. Supplementary Table 1 shows the comparison of clinical features between patients who did and did not undergo bladder POCUS among Groups B and C with AGN3 core >0. The proportion of women was higher among Group C patients who underwent POCUS. Patients in Groups B and C who did not receive POCUS had a higher rate of catheterization. We did not further analyze whether a urinary catheter was placed before or after the POCUS study. Patients who underwent POCUS in Group B had longer hospital stays, higher discharge Barthel Index and mRS scores, and higher rates of unfavorable outcomes, but there were no significant differences between Group C. Eighty-five (45%) of 190 patients with an AGN3 score >3 among Groups B and C underwent POCUS studies. The incidence of unfavorable outcomes did not differ between patients who did and did not undergo POCUS studies. Although the rate of UTI in patients with POCUS studies (11/85 = 12.9%) was higher than that in patients without POCUS studies (6/105 = 5.7%), it did not reach statistical significance (P = 0.1235). Among these 190 patients with AGN3 score >3, the catheterization rate was significantly higher in those who did not undergo POCUS (49% vs. 24%, P = 0.0005). The mean AGN3 score was also higher in patients who underwent urinary catheterization (2.6 ± 1.4 vs. 1.4 ± 1.3, P < 0.0001). For patients who already underwent early catheterization due to significant urinary dysfunction at admission, POCUS examination was not necessary. Early catheterization before POCUS studies could potentially reduce the incidence of UTI.

Table 2 summarizes the correlations of various clinical features with UTI and unfavorable outcomes in all 2848 patients. Compared with patients without UTI, those with UTI were older, had higher initial NIHSS and AGN3 scores, were more likely to be female and to have undergone indwelling urinary catheterization, had a longer hospital LOS, and experienced worse discharge outcomes. Similar results were identified in patients with unfavorable outcomes when compared with those with favorable outcomes, with the additional finding of a significantly higher PVRU volume in patients with unfavorable outcomes. The ROC curve analysis revealed that the optimal

Table 1: Summary of clinical features of 2884 patients with acute ischemic stroke

Characteristics	Total (*n*=2848)	Group A (*n*=1104)	Group B (*n*=824)	Group C (*n*=920)	*P*
Age (years)	70.6±13.4	69.9±13.5	71.6±13.8	70.7±12.9	0.0217
NIHSS score on admission	5.3±5.2	5.3±5.0	5.5±5.7	5.2±5.1	0.3940
Age ≥75 years	1145 (40)	447 (40)	372 (45)	373 (41)	0.0764
Female gender	1215 (43)	490 (44)	321 (39)	404 (44)	0.0378
NIHSS total score ≥5	1107 (39)	454 (41)	297 (36)	356 (39)	0.0765
NIHSS conscious score ≥1	307 (11)	125 (11)	104 (13)	78 (8)	0.0157
NIHSS leg score ≥2	711 (25)	262 (24)	212 (26)	237 (26)	0.4811
AGN3 score	1.6±1.4	1.6±1.3	1.6±1.4	1.5±1.4	0.4004
AGN3 score ≥1	2109 (74)	841 (76)	605 (73)	663 (72)	0.0975
Bladder POCUS study in all patients	601 (21)	0	254 (31)	370 (40)	<0.0001
Bladder POCUS in AGN3 ≥1	531/1268 (42)	-	202/605 (33)	329/663 (50)	<0.0001
AGN3 ≥1 in bladder POCUS	531/601 (88)	-	202/254 (80)	329/347 (95)	<0.0001
PVRU volume (mL)	110±91	-	114±78	108±99	0.4631
PVRU volume >100 mL	255 (14.6)	-	120 (14.6)	135 (14.7)	0.9479
Urinary catheterization	346 (12)	91 (8.2)	108 (13)	147 (16)	<0.0001
UTI	128 (4.5)	76 (6.9)	33 (4.0)	19 (2.1)	<0.0001
Hospital LOS	12.7±11.0	13.6 ±12.6	11.9±10.8	12.1±9.0	0.0012
NIHSS score at discharge	4.2±5.7	4.3±5.5	4.4±5.7	3.9±5.8	0.1332
Barthel Index score at discharge	71.6±32.1	72.8±31.1	70.6±34.3	71.1±31.2	0.2898
mRS score at discharge	2.3±1.5	2.4±1.6	2.5±1.6	2.1±1.5	<0.0001
mRS score >2 at discharge	1298 (46)	514 (47)	390 (47)	394 (43)	0.1191

Data are presented as *n* (%) or mean±SD. AGN3: Age, gender, and 3 items of NIHSS, mRS: Modified Rankin Scale, NIHSS: National Institutes of Health Stroke Scale, POCUS: Point-of-care ultrasound, PVRU: Postvoid residual urine, LOS: Length of stay, UTI: Urinary tract infection, SD: Standard deviation

PVRU volume cutoff for UTI was ≥100 mL in Groups B and C, consistent with our previous study [6].

Multivariable regression analysis of AGN3 criteria predicting UTI occurrence revealed that all items, except for NIHSS leg score ≥2, were significant predictors of UTI. Among the predictors, urinary catheterization and NIHSS total score ≥5 exhibited the top two with the highest odds ratio [Table 3]. Similarly, all items in the AGN3 criteria (including NIHSS leg score ≥2), positive UTI status, and receipt of urinary catheterization were significant factors influencing unfavorable outcomes. The C-statistic for the AGN3 criteria in predicting UTI was 0.814 [0.830–0.833; Supplementary Table 2 and Figure 1].

Nearly three-quarters (74%) of the enrolled patients met the AGN3 criteria [Table 1]. Performing bladder POCUS for all eligible patients under the AGN3 criteria can be a time-consuming and labor-intensive task. The proportions of patients with UTI were 0.1% among patients with an AGN3 score of 0 and 25% among patients with an AGN3 score of 5 [Figure 2a]. Spearman's rank correlation analysis revealed a significant positive correlation between the proportion of patients with a UTI and AGN3 scores [*P* = 0.005; Figure 2b]. ROC curve analysis was conducted to determine the Youden index, revealing an optimal AGN3 score of ≥2, yielding a sensitivity of 70.3 and a specificity of 78.1 for predicting UTI. Only 14 (1%) of 1550 patients with an AGN3 score of <2 had a UTI. Therefore, bladder POCUS may not be required for patients with an AGN3 score of <2. Selecting ≥2 as the cutoff AGN3 score would indicate that only 1298 (46%) of 2848 patients required bladder POCUS, covering 114 (89%) of the 128 patients with a UTI with an AGN3 score of ≥2.

Discussion

Incomplete emptying of urine during urination results in increased PVRU volume, which can lead to a UTI, particularly in patients with ambulatory-dependent acute stroke. Unrecognized urinary retention is common in acute stroke, and an increase in PVRU volume may cause overflow incontinence, making it appear as though a patient is voiding normally. In the present study, we reconfirmed ≥100 mL as the cutoff PVRU volume for the development of UTI. Other

Table 2: Correlations of clinical features with urinary tract infection and unfavorable outcomes in 2848 patients with acute ischemic stroke

Characteristics	UTI			Unfavorable outcomes		
	Yes (*n*=128)	No (*n*=2720)	*P*	Yes (*n*=1298)	No (*n*=1550)	*P*
Age (years)	78.1±11.0	70.3±13.4	<0.0001	66.5±12.8	75.4±12.5	<0.0001
Initial NIHSS on admission	12.1±8.1	4.9±23.3	<0.0001	8.3±6.1	2.9±2.6	<0.0001
Age ≥75 years	90 (70)	1102 (41)	<0.0001	735 (57)	410 (26)	<0.0001
Female gender	85 (66)	1130 (42)	<0.0001	662 (51)	553 (36)	<0.0001
NIHSS total score ≥5	104 (81)	1003 (37)	<0.0001	852 (66)	255 (16)	<0.0001
NIHSS conscious score ≥1	50 (39)	257 (9)	<0.0001	262 (20)	45 (3)	<0.0001
NIHSS leg score ≥2	76 (59)	635 (23)	<0.0001	597 (46)	114 (7)	<0.0001
AGN3 score	3.1±1.2	1.5±1.3	<0.0001	2.4±1.4	0.9±0.9	<0.0001
AGN3 score ≥1	127 (99)	1982 (73)	<0.0001	1191 (92)	918 (59)	<0.0001
Urinary catheterization	60 (47)	286 (11)	<0.0001	290 (22)	56 (4)	<0.0001
PVRU volume (mL)	142±73	109±91	0.0674	119±90	100±91	0.0132
PVRU volume >100 mL	18 (35)	237 (14)	<0.0001	153 (20)	102 (11)	<0.0001
Hospital LOS	27.6±16.7	11.9±10.2	<0.0001	18.6±12.8	7.7±5.7	<0.0001
NIHSS score at discharge	11.5±9.2	3.8±5.2	<0.0001	7.5±7.0	1.5±1.4	<0.0001
Barthel Index score at discharge	27.5±27.8	73.7±30.7	<0.0001	43.9±27.8	94.2±9.9	<0.0001
mRS score at discharge	4.2±1.1	2.2±1.6	<0.0001	3.8±1.1	1.0±0.6	<0.0001
mRS score >2 at discharge	119 (93)	1179 (43)	<0.0001	-	-	-

Data are presented as *n* (%) or mean±SD. AGN3: Age, gender, and 3 items of NIHSS, mRS: Modified Rankin Scale, NIHSS: National Institutes of Health Stroke Scale, POCUS: Point-of-care ultrasound, PVRU: Postvoid residual urine, LOS: Length of stay, SD: Standard deviation

Table 3: Regression model of factors influencing urinary tract infection and unfavorable outcomes in 2848 patients with acute ischemic stroke

Characteristics	UTI		Unfavorable outcomes	
	OR (95% CI)	*P*	OR (95% CI)	*P*
Age ≥75 years	1.951 (1.298–2.935)	0.0013	3.120 (2.575–3.781)	<0.0001
Female gender	1.828 (1.225–2.726)	0.0031	1.318 (1.091–1.594)	0.0043
NIHSS total score ≥5	3.357 (1.967–5.727)	<0.0001	4.709 (3.791–5.850)	<0.0001
NIHSS conscious score ≥1	2.031 (1.322–3.119)	0.0012	1.907 (1.290–2.818)	0.0001
NIHSS leg score ≥2	1.292 (0.830–2.012)	0.2566	3.167 (2.422–4.141)	<0.0001
Urinary catheterization	3.610 (2.421–5.383)	<0.0001	3.227 (2.273–4.581)	<0.0001
UTI	-	-	4.345 (2.048–9.222)	<0.0001

CI: Confidence interval, NIHSS: National Institutes of Health Stroke Scale, OR: Odds ratio, UTI: Urinary tract infection

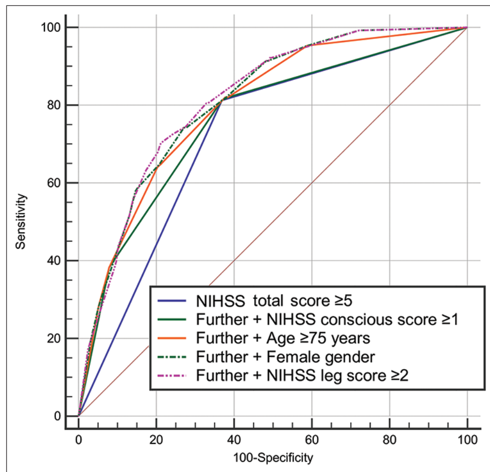

Figure 1: C-statistic analysis of AGN3 criteria for predicting urinary tract infection, stepwise summation from the National Institutes of Health Stroke Scale (NIHSS) total score ≥5 to NIHSS leg score ≥2. NHSS: National Institutes of Health Stroke Scale

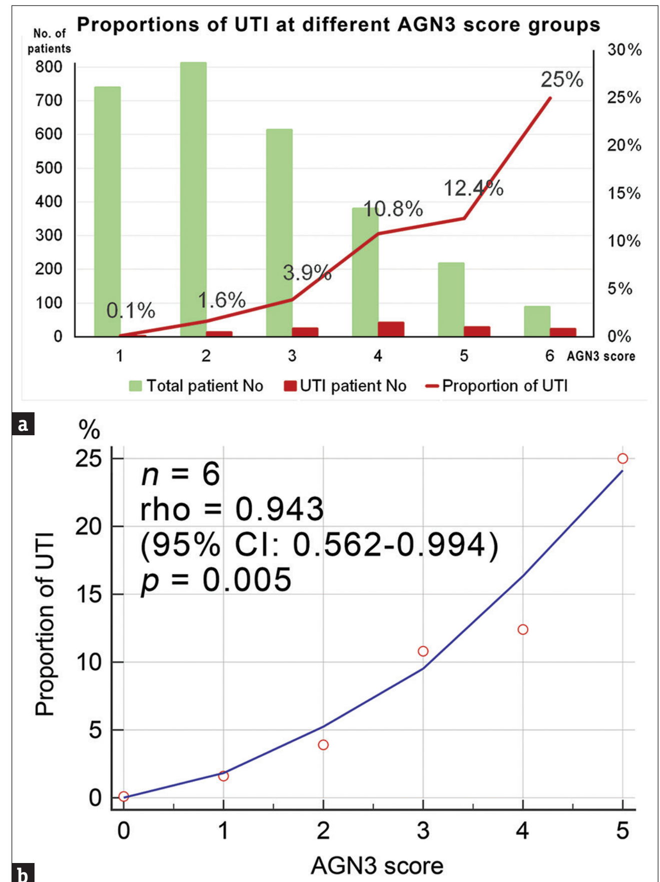

Figure 2: Proportion of patients with urinary tract infection (UTI) increases significantly, with AGN3 score increasing from 0 to 5 (a). Spearman's rank correlation analysis reveals a significantly positive correlation between the proportion of patients with UTI and AGN3 score (b). UTI: Urinary tract infection, CI: Confidence interval

studies have reported that immune-inflammatory response during AIS (stroke-induced immunodepression) may increase the risk of respiratory infection or UTI [8,9]. Lin *et al.* reported that high initial stroke severity (NIHSS score ≥5), older age (age >75 years), and female gender were significant predictors of unfavorable outcomes [10]. We demonstrated in another study that NIHSS total score ≥5, age ≥75 years, and female gender were significant predictors of UTI risk, leading to their inclusion in the AGN3 criteria [6]. The AGN3 criteria further incorporated NIHSS conscious score ≥1 and NIHSS leg score ≥ 2 to account for the ability to independently ambulate from the bed to the toilet. With these three simple clinical features (age, gender, and NIHSS scores), physicians and nurses can quickly identify patients who are at risk of UTI upon admission without requiring further information, such as stroke location, comorbidities, or laboratory results.

We recommended in another study that bladder POCUS be given to patients who meet at least one of the five AGN3 criteria [6]. In July 2021, we implemented the AGN3 criteria in our stroke ward. We use a more convenient, wireless, pocket-sized ultrasound device for bladder POCUS. The present study provides insights on the real-world clinical application of bladder POCUS based on the AGN3 criteria. In Group C, 95% of patients who received bladder POCUS had an AGN3 score of ≥1; however, only 50% of those with an AGN3 score of ≥1 received bladder POCUS. This indicates a high compliance rate but a suboptimal implementation rate for bladder POCUS. One confounding factor contributing to the suboptimal implementation rate is the study period of Group C, which coincided with the COVID-19 pandemic, during which nonurgent medical procedures, such as bladder POCUS, were postponed. UTI mechanisms are multifactorial and not solely due to urinary retention. Nonetheless, the implementation of bladder POCUS significantly reduced the incidence of UTI and shortened hospital LOS, particularly in Group C, where the incidence of UTI was reduced by 70% compared with Group A (6.9% vs. 2.1%). Group C had the highest catheterization rate, possibly because of the subsequent management of early detected urinary retention through bladder POCUS. The reason for urinary catheterization was mostly due to a distended bladder that was discovered after UTI or after routine bladder POCUS. However, indwelling urinary catheterization has both beneficial and adverse effects. Prolonged urinary catheterization without proper Foley care is a risk factor for UTI. Although the incidence of UTI was significantly lower in Group C, no significant difference in discharge outcomes was identified among the three groups. A possible explanation is that ongoing efforts to improve urinary care have reduced UTI incidence to a negligible level.

A higher implementation rate for bladder POCUS is associated with a lower incidence of UTI, and the incidence of UTI increases with higher AGN3 scores. While no difference of UTI rates was observed between patients who did and did not undergo bladder POCUS in the present study. Although data were retrieved from three patient groups over different time periods, most baseline characteristics did not differ significantly. The incident of UTI significantly decreased from Group A to Group C. Unlike therapeutic procedures, the role of bladder POCUS is to quickly and easily screen patients at increased risk for UTI. In real-world practice, patients with higher PVRU volume do not necessarily develop UTIs. It is difficult to demonstrate the pure impact of bladder POCUS

on UTI prevention. The decline in UTI incidence is not attributable solely to bladder POCUS. For patients with PVRU volume >100 mL, clinical pathways including medical therapy and/or catheterization play an important role in preventing UTI. The improvement of patient care evolved over time, and the awareness and health education brought about by the implementation of bladder POCUS have also increased the attention of medical staff and patients to urination problem. In addition, although no UTI occurred during hospitalization, early detection of urinary retention in asymptomatic high-risk patients can help prevent subsequent severe neurogenic bladder after discharge. If the recommendation that patients with an AGN3 score of ≥1 require bladder POCUS is strictly applied, 74% of the enrolled inpatients would meet the criteria. However, the incidence of UTI was low in our study cohort. A more practical and feasible method for efficiently identifying eligible patients for bladder POCUS is necessary. In the present study, ≥2 was identified as the optimal cutoff AGN3 score for predicting UTI. With this revised standard, bladder POCUS would be required for only 46% of all patients to capture 89% of UTI cases. This is closer to the 40% implementation rate in Group C, suggesting increased clinical feasibility.

Advancements in ultrasound technology have led to the development of high-resolution, cost-effective, and portable ultrasound devices, creating new avenues for the clinical application of POCUS. Two primary models of ultrasound devices are available for bladder POCUS. The first model employs bladder visualization using real-time B-mode to measure the diameter of the urinary bladder and determine the PVRU volume. The second model enables the rapid estimation of PVRU volumes through automated three-dimensional scanning without requiring real-time urinary bladder visualization (the "blind method"). Chang *et al*. compared these models and revealed that automated three-dimensional scanning ultrasound was more effective for learning and scanning, but exhibited greater measurement deviations. Real-time B-mode ultrasound was demonstrated to more accurately visualize the urinary bladder but tended to underestimate the PVRU volume if the bladder is overdistended due to too much urine [11]. The primary benefit of bladder POCUS lies not in its ability to accurately measure PVRU volume but instead in its ability to detect UTI early and facilitate subsequent clinical decision-making. We also established a standardized clinical pathway for patients with a PVRU volume of >100 mL to prevent UTI. Repeat bladder POCUS is necessary to confirm urinary retention, followed by intermittent catheterization to drain urine or indwelling Foley catheterization for severe urine retention cases. Depending on the causes of urinary retention, medication may be required, particularly for patients with a diabetic neurogenic bladder and older men with prostate hypertrophy [12].

Bladder POCUS is a rapid, convenient, and reliable bedside examination for detecting PVRU [4]. After 10 min of short-term training, a resident physician or nurse can complete the procedure within 5–10 min and with measurement deviations within an acceptable range [11]. With POCUS devices becoming increasingly affordable, a more proactive model should be established for achieving a balance between patient safety and medical costs. Furthermore, AGN3 scores can be quickly and directly assessed on the basis of stroke severity upon admission by physicians or nurses in a stroke ward, requiring no laboratory data or stroke location information. Bladder POCUS should be conducted for patients with an AGN3 score of ≥2 at least once within the 1st week of hospitalization to estimate PVRU volume. The reductions in UTI incidence and hospital LOS justify the associated medical and labor expenses.

The present study has several limitations. First, the incidence of UTI among all enrolled inpatients could be higher if patients with severe stroke who were initially admitted to the intensive care unit were enrolled. Although patients with severe stroke who are admitted to the intensive care unit are often bedridden and receive comprehensive care, including assessment of urinary function, prolonged Foley catheter use and impaired immune response could increase their UTI risk. Second, bladder POCUS examinations were not consistently performed by the same operator. In addition to long-term care resident physicians and advanced-practice registered nurses, rotatory resident physicians also participated in performing bladder POCUS. Nonetheless, quality control for our ultrasound study was maintained through adequate training that incorporated a procedural video. Third, the hospital LOS was not significantly shorter in Group C than in Group B. This may be partially attributed to the year-over-year increase in the proportion of patients participating in the postacute care model for stroke established by the National Health Insurance Bureau of Taiwan, in which patients with acute stroke occurring within 30 days and with an mRS score of 3–4 can be transferred to postacute care hospitals for 6–12 weeks of rehabilitation [13]. The proportion of patients participating in the postacute care stroke model reached 22% in 2022 at the index hospital. Serial assessments at upstream index and downstream postacute care hospitals, along with patient discretion before transfer, may prolong the hospital LOS in Group C. Fourth, because not every patient had accurate records of the exact time of catheterization during hospitalization, the relationship between UTI and catheterization could not be clearly determined.

Conclusion

Bladder POCUS is beneficial for reducing UTI incidence and hospital LOS in patients with AIS. Patients with an AGN3 score of ≥2 were at higher risk for UTI, making bladder POCUS studies particularly beneficial for this group.

Data availability statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Conflicts of interest

There are no conflicts of interest.

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Supplementary material

Supplementary Table 1: Comparison of clinical features between patients who did and did not undergo bladder point-of-care ultrasound among Groups B and C with an AGN3 core >0

Characteristics	Group B (*n*=605)			Group C (*n*=663)			Groups B and C (*n*=1268)		
	POCUS (−) (*n*=403)	POCUS (+) (*n*=202)	*P*	POCUS (−) (*n*=334)	POCUS (+) (*n*=329)	*P*	POCUS (−) (*n*=737)	POCUS (+) (*n*=531)	*P*
Age (years)	75.2±12.5	76.8±12.5	0.1239	72.9±12.9	74.7±12.1	0.0595	74.1±12.7	75.5±12.3	0.0512
Female gender	227 (56)	94 (47)	0.0248	188 (56)	216 (66)	0.0138	415 (56)	310 (58)	0.4901
NIHSS score on admission	6.4±6.4	7.2±5.7	0.1267	6.6±5.4	6.3±5.6	0.4367	6.5±5.9	6.6±5.6	0.7051
AGN3 score	2.1±1.2	2.3±1.2	0.0264	2.1±1.1	2.2±1.1	0.2503	2.1±1.2	2.2±1.1	0.0254
Urinary catheterization	80 (20)	21 (10)	0.0037	87 (26)	47 (14)	0.0002	167 (23)	68 (13)	<0.0001
UTI	18 (4.5)	14 (6.9)	0.2472	7 (2.1)	12 (3.6)	0.2531	25 (3.4)	26 (4.9)	0.1937
Hospital LOS	12.3±10.6	16.5±12.7	<0.0001	13.4±10.2	13.3±8.6	0.9046	12.8±10.4	14.5±10.5	0.0033
NIHSS at discharge	5.2±6.7	5.8±5.4	0.3023	5.0±6.7	4.5±5.8	0.2687	5.1±6.7	4.9±5.7	0.6381
Barthel Index score at discharge	65.2±36.3	56.0±33.3	0.0042	62.5±34.3	65.6±30.8	0.2196	63.9±35.4	62.2±32.1	0.3777
mRS score at discharge	2.8±1.6	3.2±1.5	0.0031	2.4±1.5	2.4±2.2	0.8997	2.6±1.6	2.7±1.9	0.3340
mRS score >2 at discharge	227 (56)	140 (69)	0.0011	178 (53)	172 (52)	0.8157	402 (55)	312 (59)	0.1515

−: Did not undergo POCUS study, +: Did undergo POCUS study. Data are presented as *n* (%) or mean±SD. AGN3: Age, gender, and 3 items of NIHSS, mRS: Modified Rankin Scale, NIHSS: National Institutes of Health Stroke Scale, POCUS: Point-of-care ultrasound, SD: Standard deviation, LOS: Length of stay, UTI: Urinary tract infection

Supplementary Table 2: C-statistic of age, gender, and 3 items of National Institutes of Health Stroke Scale criteria for predicting urinary tract infection

Characteristics	OR (95% CI)	*P*
NIHSS total score ≥5	0.722 (0.680–0.763)	
Includes NIHSS conscious score ≥1	0.761 (0.718–0.805)	<0.0001
Further includes age ≥75 years	0.796 (0.759–0.834)	<0.0001
Further includes female gender	0.809 (0.776–0.843)	0.0015
Further includes NIHSS leg score ≥2	0.814 (0.830–0.883)	0.3076

NIHSS: National Institutes of Health Stroke Scale, AGN3: Age, gender, and 3 items of NIHSS, OR: Odds ratio, CI: Confidence interval