Research Article

Predicting complicated outcomes in spinal cord injury patients with urinary tract infection: Development and internal validation of a risk model

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Context/objective: Patients with chronic SCI hospitalized for UTI can have significant morbidity. It is unclear whether SIRS criteria, SOFA score, or quick SOFA score can be used to predict complicated outcome.

Design: Retrospective cohort study. A risk prediction model was developed and internally validated using bootstrapping methodology.

Setting: Urban, academic hospital in St. Louis, Missouri.

Participants: 402 hospitalizations for UTI between October 1, 2010 and September 30, 2015, arising from 164 patients with chronic SCI, were included in the final analysis.

Outcome/measures: An *a priori* composite complicated outcome defined as: 30-day hospital mortality, length of hospital stay > 4 days, intensive care unit (ICU) admission, and hospital revisit within 30 days of discharge.

Results: Mean age of patients was 46.4 ± 12.3 years; 83.6% of patient-visits involved males. The primary outcome occurred in 278 (69.2%) hospitalizations. In multivariate analysis, male sex was protective (odds ratio [OR], 0.43; 95% confidence interval [CI], 0.18-0.99; $P = 0.048$) while Gram-positive urine culture (OR 3.07; 95% CI, 1.05-9.01; $P = 0.041$), urine culture with no growth (OR, 1.69; 95% CI, 1.02-2.80; $P = 0.041$), and greater SOFA score (for one-point increments, OR, 1.41; 95% CI, 1.18-1.69; $P < 0.001$) were predictive for complicated outcome. SIRS criteria and qSOFA score were not associated with complicated outcome. Our risk prediction model demonstrated good overall performance (Brier score, 0.19), fair discriminatory power (c-index, 0.72), and good calibration during internal validation.

Conclusion: Clinical variables present on hospital admission with UTI may help identify SCI patients at risk for complicated outcomes and inform future clinical decision-making.

Keywords: Urinary tract infection, Spinal cord injury, Systemic inflammatory response syndrome, Sequential organ failure assessment score, Risk prediction model

Introduction

Chronic spinal cord injury (SCI) is a common and devastating condition, with an estimated 282,000 survivors of traumatic SCI living in the United States.¹ Numerous studies have identified urinary tract infection

(UTI) as the most common secondary medical complication afflicting SCI patients and a frequent cause for hospitalization.²⁻⁵ Profound alterations in urodynamic function and reliance on urinary catheterization for bladder drainage increase the risk of UTI among patients living with chronic SCI, resulting in an estimated rate of 2.5 episodes of UTI per patient per year.⁶⁻⁸ These infections carry significant risk of morbidity, including kidney injury from parenchymal

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inflammation and scarring, renal calculi, and concomitant bloodstream infection.^{9–11}

Severe infections in SCI patients can prove to be a diagnostic challenge due to a lack of local symptomatology. Delayed diagnosis in this population may contribute to the significant morbidity, not only via late administration of antibiotics or source control, but also by prolonging hospitalization, interfering with rehabilitation, and predisposing the patient to malnutrition and deconditioning. Traditionally, the identification of sepsis was dependent on physiologic changes in body temperature, heart rate, and respiratory rate, which can be masked by autonomic dysfunction in the setting of chronic SCI. It is not known whether these parameters can be relied upon to identify sepsis and predict adverse outcomes due to infection in individuals with SCI. Sepsis has been reconceptualized as life-threatening organ dysfunction due to a dysregulated response to infection, and recently updated guidelines recommend the use of the Sequential Organ Failure Assessment (SOFA) score and quick SOFA (qSOFA) score to identify patients with suspected infection likely to have poor outcomes in ICU and non-ICU settings, respectively.^{12,13}

Associations between systemic inflammatory response syndrome (SIRS) criteria, SOFA score, and qSOFA score with clinical outcomes in patients with chronic SCI have not been well-described. Likewise, prognostic models to identify chronic SCI patients at risk for adverse outcomes from UTI do not exist. Given that early recognition of high-risk patients can influence clinical decision-making and improve outcome, we evaluated the association between the physiological responses to infection (SIRS criteria and hypotension) and measures of severity of illness (SOFA and qSOFA scores) with complicated outcomes. Next, we developed and internally validated a clinical prediction model for adverse or complicated outcome in chronic SCI patients presenting with UTI.

Methods

Study location

A single-center retrospective cohort study was conducted at a 1,250-bed university-affiliated, urban academic hospital in Saint Louis, Missouri, USA. This study was approved by the Washington University School of Medicine Human Research Protection Office.

Population

All patients aged 18 years or older with a chronic cervical or thoracic SCI who were admitted with UTI over a 5-year period from October 2010 to October 2015 were eligible for inclusion. Patients were identified as having

cervical or thoracic SCI above level T7 using the following International Classification of Diseases, Ninth Revision, Clinical Modification codes: 344.00–344.04, 344.09, 344.1, 806.00–806.19, 806.20–806.24, 806.30–806.34, or 952.00–952.14. Cervical or thoracic SCI was further defined as chronic if the initial inciting event occurred at least one year prior to the patient's hospitalization for UTI. A diagnosis of UTI was determined by the following ICD-9-CM codes: 590.1, 595.0, or 599.0, which was then confirmed by the presence of symptoms of UTI (change in appearance or odor of urine, suprapubic or flank pain, dysuria, subjective fever, chills, night sweats, nausea or vomiting, and malaise) and laboratory evidence of pyuria (urine dipstick test positive for leukocyte esterase or greater than 2 white cells/high-power field of unspun urine) or bacteriuria (urine specimen with isolation of an organism in quantitative counts of greater than 100,000 colonies/mL). Patients were excluded from the study if they did not have vital signs and laboratory data obtained within 24 hours of presentation, including complete blood count, urinalysis with microscopic examination, and urine culture, or if they were diagnosed with another significant concomitant infection, such as pneumonia or osteomyelitis.

Study design and data collection

We collected data on patient demographics, comorbid illnesses, clinical presentation (including initial vital signs), laboratory variables, and outcomes from electronic health records, inpatient pharmacy database, and laboratory database. The primary outcome was an *a priori* outcome of complications, including 30-day mortality, length of hospital stay >4 days, intensive care unit admission, and hospital revisit (emergency department and direct hospital admission) within 30 days of hospital discharge. Patient records were reviewed to verify the primary outcome. Patient predictor variables were prospectively selected prior to the initiation of the study based on earlier studies, and threshold values were selected to convert certain continuous variables to dichotomous variables in accordance with prior established literature.^{6,7,23}

Acute Physiology and Chronic Health Evaluation (APACHE) II, SOFA, and qSOFA scores were computed based on clinical data collected within the first 24 hours of presentation, with the highest value for each score used in the final analysis.

Definitions

We defined SIRS criteria according to the American College of Chest Physicians – Society of Critical Care Medicine consensus definition.⁶ Patients were classified

as hypotensive if their systolic blood pressure was less than 90 mmHg or if their mean arterial pressure was less than 65 mmHg. Vasopressor use was defined as the use of norepinephrine, dopamine, dobutamine, epinephrine, phenylephrine, or vasopressin at any point during hospitalization. To fulfill a diagnosis of UTI with secondary bacteremia, the same organism must have been cultured from urine and blood specimens collected within 24 hours of each other. Antimicrobial therapy was considered appropriate if the initially prescribed antibiotic regimen was active against the organism cultured based on *in vitro* susceptibility testing and given within 24 hours of patient presentation. With regards to polymicrobial UTI, the initial antibiotic regimen had to be active against all isolated organisms to be deemed appropriate. In cases where urine culture failed to isolate an organism, antimicrobial therapy was not included in the analysis.

Statistical analysis

Data analysis was performed using Statistical Analysis System 9.4 (SAS Institute, Cary, NC) and “geepack” package 1.2-1 in R.¹⁴ Statistical tests were two-tailed, and a P-value < 0.05 was established as the cutoff for statistical significance. Demographic and clinical variables were compared between patients with and without a composite complicated outcome using univariate analysis (with use of the Fisher’s exact test for small sample sizes) in order to determine putatively significant prognostic variables. Candidate variables that were associated with the composite complicated outcome in univariate analysis ($P < 0.05$) and those deemed clinically significant were included in multivariable analysis. These results were reported as multivariable adjusted odds ratios with 95% confidence intervals. In order to take into account the effect of repeated observations and potential clustering within

the data, generalized estimating equations (GEEs) were used to develop the final risk model. For GEE analysis, an exchangeable working correlation structure was assumed and the robust variance estimator was used for statistical inference. Variables with a P-value < 0.05 in multivariable analysis were retained for inclusion in the GEE model, but predictors that were considered to have clinical relevance were also forced back into the model.

For continuous variables, we examined the strength and shape of their relationship to the log odds of a complicated outcome using restricted cubic spline functions.¹⁵ When possible, these functions were simplified using piecewise linear splines for clearer interpretation of regression coefficients. These functions were graphically examined and statistically compared using the log likelihood ratio test to assess the relationship between continuous variables and the log odds of a complicated outcome. The optimal spline model was determined by minimizing the Akaike Information Criterion (AIC) value.

The overall performance of the model was assessed by the Brier score. Calibration and discriminative ability were also used to characterize the predictive performance of the model. The calibration of the model is the agreement between observed outcomes and predictions. The calibration slope is related to the average strength of predictor effects, and ideally the slope should equal one. The calibration intercept indicates the degree to which the predictions are systematically too low or too high, as the optimal value should equal zero. The c-index, or area under the receiver operating characteristic (ROC) curve, was calculated as a measure of predictive discrimination of the model. The predictive performance of the model was internally validated through bootstrapping in the original data set by sampling with replacement for 1,000 iterations. Assessment of spline terms and internal validation of the model were performed using the “rms” package 4.4-1 in R.^{16,17}

Results

We identified 549 initial patient-visits for individuals with SCI hospitalized with UTI during the study period. Of these, 147 patient-visits were excluded (Fig. 1). 402 patient-visits arising from 164 individual patients were ultimately included in the analysis. Symptoms of UTI on presentation included suprapubic/flank pain or dysuria (55.7%), change in the appearance or odor of urine (44.8%), subjective chills (40.8%) or fever (36.6%), nausea or vomiting (25.9%), and malaise (19.9%). Pyuria was detected in 400 (99.5%) patient-visits, and although bacteriuria was found on

Figure 1 Patient exclusions.

urine microscopy in 380 (94.5%) patient-visits, true bacteriuria was confirmed for 231 (57.5%) patient-visits.

The mean age of the population was 46.4 ± 13.4 years with a range from 20-87 years and 130 (79.3%) of the patients were males (Table 1). Summary statistics of clinical features, including vital signs, severity of illness scores, and laboratory values, are presented in Table 2.

Of the initial urine cultures collected upon admission, 24 (6.0%) yielded a Gram-positive organism, 160 (39.8%) a Gram-negative organism, and 47 (11.7%) were polymicrobial. 12 episodes of UTI were complicated by secondary bacteremia. Among urine culture isolates, 77 (19.2%) yielded antibiotic-resistant organisms. Appropriate initial antimicrobial therapy was administered in 165 (71.4%) cases.

Clinical outcomes for the 402 patient visits are also presented in Table 2. Of note, 91 (22.6%) patient-visits met criteria for two different adverse outcomes and 15 (3.7%) patient-visits met criteria for three different adverse outcomes.

Patients with chronic SCI admitted for UTIs were more likely to experience a complicated outcome based on univariate analysis if they were older, female, had a more severe illness based on severity-of-disease scores, had an elevated heart rate or respiratory rate, fulfilled a greater number of SIRS criteria, required vasopressor use, or were urine culture-positive for certain organisms ($P < 0.05$) (Table 2). Upon multivariable analysis, female sex, increasing SOFA scores, and Gram-positive urine culture and urine culture with no growth in comparison to Gram-negative urine culture were independently associated with our composite complicated outcome (Table 3).

Sex, SOFA score, and urine culture pathogen were included as risk factors for a composite complicated outcome in our model. Two additional variables, age and elevated heart rate, were forced back into the final

risk prediction model based on clinical relevance (Table 4). Only age, urine culture with no growth, and SOFA score were determined to be significant in the final GEE model. In the development set, the c-index was 0.7177 and the Brier score was 0.1865. The calibration plot for the predictive model generated during development is depicted in Fig. 2, with the calibration slope = 0.9941 and the calibration intercept = 0.0661. The performance of the model during internal validation using bootstrap methodology resulted in a c-index of 0.7045 (95% CI, 0.6803 to 0.7206) and a Brier score of 0.1921 (95% CI, 0.1877 to 0.2008), with a calibration slope of 0.7913 (95% CI, 0.4606 to 1.0474) and calibration intercept of 0.2056 (95% CI, -0.0487 to 0.5117).

Discussion

UTIs can lead to significant morbidity among patients with chronic SCI. Accurate tools for identifying patients at increased risk for adverse or complicated outcomes are lacking. We developed and internally validated a novel risk prediction model in patients with chronic SCI with good overall performance in predicting a composite adverse outcome from hospitalization with UTI. Our model incorporates five clinical parameters that are readily available to practitioners (age, sex, heart rate, SOFA score, and urine culture result). In addition, we investigated the relationship between the acute physiological disturbances from infection, traditionally identified as SIRS criteria, with an adverse outcome in this patient population. We found that no single SIRS criterion or number of SIRS criteria fulfilled, nor the presence of hypotension, was associated with a composite complicated outcome for patients with chronic SCI hospitalized with UTI. Instead, we demonstrated that severity of organ dysfunction, as assessed by SOFA score, is a significant predictor of outcome in this population. These results have several implications.

The clinical signs described by SIRS criteria are meant to reflect an aberrant physiological response to inflammation in the setting of infection, and hence severity of illness. Yet, in our study population of SCI patients with UTI, this does not appear to be true. No single SIRS criteria was associated with an adverse outcome. One explanation for this finding may be that hemodynamic, thermoregulatory, and autonomic dysregulation following SCI may blunt or mask physiological responses to infection, even when severe. The absolute number of SIRS criteria fulfilled was also not linked to a complicated outcome, in contrast with prior studies in the general population.^{18,19} A significant

Table 1 Patient demographics and baseline characteristics.

Variable	Value
No. (%) with data	164 (100)
Age, mean (SD), years	46.4 (13.4)
Ethnicity, number (%)	
White	62 (37.8)
Non-white	102 (62.2)
Male, number (%)	130 (79.3)
Level of spinal cord injury, number (%)	
Cervical	46 (28.0)
Thoracic	118 (72.0)
Comorbidities, number (%)	
Chronic kidney disease	2 (1.2)
Diabetes mellitus	32 (19.5)
HIV infection	6 (3.7)

Table 2 Univariate analysis for predictors of complicated outcome.

Variable	Uncomplicated (n = 124)	Complicated (n = 278)	Adjusted OR	95% CI	P- value
Demographics					
Age, mean (SD), y	44.5 ± 11.7	47.3 ± 12.4	1.019	1.000–1.039	0.050
Male (%)	112 (90.3)	224 (80.6)	0.444	0.215–0.919	0.029
Chronic indwelling urinary catheter (%)	8 (6.5)	12 (4.3)	0.654	0.282–1.519	0.32
Clinical Presentation					
Temperature > 38°C (%)	10 (8.1)	34 (12.2)	1.589	0.704–3.586	0.26
Temperature < 36°C (%)	7 (5.7)	12 (4.3)	0.754	0.314–1.809	0.53
Heart rate > 90 beats per minute (%)	71 (57.3)	199 (71.6)	1.880	1.149–3.076	0.012
Respiratory rate > 20 respirations per minute (%)	21 (16.9)	82 (29.5)	2.052	1.130–3.726	0.018
WBC > 12,000/mm ³ (%)	53 (42.7)	133 (47.8)	1.229	0.770–1.961	0.39
Number of SIRS criteria, mean (SD)	1.3 ± 1.0	1.7 ± 1.1	1.332	1.085–1.636	0.006
Hypotension (%)	33 (26.6)	101 (36.3)	1.573	0.914–2.710	0.10
APACHE II score, mean (SD)	6.6 ± 3.0	8.1 ± 4.5	1.019	1.000–1.039	0.005
SOFA score, mean (SD)	1.0 ± 1.0	1.9 ± 2.3	1.418	1.198–1.677	<0.001
qSOFA score, mean (SD)	0.7 ± 0.6	0.9 ± 0.9	1.510	1.109–2.055	0.009
Vasopressor use (%) ^a	0 (0)	34 (12.2)			<0.001
Cr >2.0 mg/dL, No. (%) with data	123 (99.2)	278 (100)			
No. (%)	5 (4.1)	24 (8.6)	2.249	0.980–5.162	0.056
Platelets < 100,000/mm ³ (%) ^a	0 (0)	4 (1.4)			0.32
Elevated serum lactate, No. (%) with data	61 (49.2)	116 (46.8)			
No. (%)	10 (16.4)	27 (23.3)	0.864	0.386–1.933	0.75
Appropriate antimicrobial therapy, No. (%) with data	78 (62.9)	121 (48.8)			
No. (%) ^b	61 (78.2)	104 (86.0)	0.617	0.342–1.112	0.079
Antibiotic-resistant organism, No. (%) with data ^c	78 (62.9)	121 (48.8)			
No. (%)	23 (29.5)	54 (44.6)	1.331	0.712–2.491	0.14
Secondary bacteremia, No. (%) with data	47 (37.9)	82 (33.1)			
No. (%)	2 (4.3)	10 (12.2)	2.206	0.462–10.531	0.56
Urinary Culture					
Gram-positive organism (%)	4 (3.2)	20 (7.2)	3.163	1.095–9.135	0.035
Gram-negative organism (%)	62 (50.0)	98 (35.2)	Reference		
Polymicrobial (%)	13 (10.5)	34 (12.2)	1.655	0.886–3.091	0.11
No growth (%)	45 (36.3)	126 (45.3)	1.771	1.118–2.806	0.015
Hospitalization for UTI					
Duration, mean (SD), days	2.7 ± 0.9	11.0 ± 10.7			
Complicated Outcomes					
In-hospital death (%)	0 (0)	5 (1.8)			
Admission to ICU (%)	0 (0)	69 (24.8)			
Length of stay >4 days (%)	0 (0)	180 (64.7)			
Facility revisit within 30 days (%)	0 (0)	147 (52.9)			

Categorical data are expressed as number (percentage), continuous data is expressed as mean ± standard deviation. For the variables WBC < 4,000/mm³ and > 10% immature neutrophils, the adjusted odds ratios, 95% confidence intervals, and P-values could not be calculated since zero patient cases fulfilled these criteria.

^aValues calculated using Fisher's exact test.

^bPercentages calculated utilizing only cases with a positive urine culture.

^cMethicillin-resistant *Staphylococcus aureus*, vancomycin-resistant enterococci, or Gram-negative bacteria resistant to cefepime, a fluoroquinolone, piperacillin-tazobactam, or a carbapenem, as established by susceptibility testing.

fraction (33.3%) of our patients were hypotensive upon presentation, and yet, hypotension itself was not associated with a complicated outcome. Loss of sympathetic vascular tone in the context of SCI, rather than pathological circulatory dysfunction from sepsis, is one possible mechanism of hypotension in this population.

Female sex, SOFA score, Gram-positive urine culture, and urine culture with no growth were found to be significant, independent predictors of a complicated outcome from UTI in chronic SCI patients. The

SOFA score was initially developed to assess the severity of organ dysfunction and predict ICU mortality in critically ill patients, and has now been incorporated into the updated definition of sepsis.^{12,20,21} Interestingly, certain clinical components that comprise the SOFA score, including hypotension, serum creatinine, and platelet count, were not individually associated with a complicated outcome in our study population. PaO₂/FiO₂ ratio, Glasgow Coma Scale score, and serum bilirubin were not studied individually in our study, and are

Table 3 Multivariable analysis for predictors of complicated outcome.

Variable	Adjusted Odds Ratio	95% Confidence Interval	P-value
Male sex	0.427	0.184–0.992	0.048
SOFA score (one-point increments)	1.410	1.179–1.686	<0.001
Gram-positive vs. Gram-negative urine culture	3.069	1.045–9.008	0.041
Urine culture with no growth vs. Gram-negative urine culture	1.692	1.021–2.802	0.041

All variables with a P-value < 0.05 in univariate analysis were included in multivariable analysis, except for vasopressor use (zero patient cases with an uncomplicated outcome involved vasopressor use). The following variables with a P-value > 0.05 were also included: temperature > 38°C, temperature < 36°C, WBC > 12,000/mm³, hypotension, and appropriate antimicrobial therapy. Only variables with a P-value < 0.05 are shown.

likely the constituents of the SOFA score that may predict an adverse outcome from UTI in SCI patients. For patients with suspected infection outside of the ICU, the predictive validity for in-hospital mortality of qSOFA scores exceeds that of SOFA scores, and it is recommended that a positive qSOFA score should prompt consideration of sepsis.^{12,13} In our study, increasing SOFA score, but not qSOFA score, was correlated with an adverse outcome (Table 2). This may be due to the dependence of qSOFA score on derangements in vital signs (systolic blood pressure of 100

Table 4 Generalized estimating equations model.

Variable	β Coefficient	Standard Error	P-value
Intercept	-1.1398		
Age	0.0529	0.0226	0.019
Age ²	-0.1662	0.0592	0.005
Age ³	0.1788	0.0710	0.012
Male sex	-0.8321	0.4269	0.051
Heart rate >90 beats per minute	0.3815	0.2401	0.11
Gram-positive urine culture	1.0215	0.5867	0.082
Polymicrobial urine culture	0.2541	0.3186	0.43
Urine culture with no growth	0.5750	0.2288	0.012
SOFA score	-0.2542	0.2797	0.36
SOFA score ²	0.8578	0.3314	0.010

β coefficient values are expressed for the condition present in dichotomous variables and per 1-unit increase for continuous variables. The cumulative effect of age (3 terms combined) is significant with a P-value of 0.037 and the cumulative effect of SOFA score (2 terms combined) is significant with a P-value < 0.001. Age ranged from 20 to 87 years and SOFA scores ranged from 0 to 12.

Figure 2 Predicted outcome probabilities are plotted against observed outcome probabilities. Circles indicate the observed proportions of the composite complicated outcome, by tenths of predicted probability. The dashed line represents a perfect calibration line. The solid line represents the smoothed, calibration line for our model.

mmHg or less and respiratory rate 22/min or greater) which, as elucidated earlier, are not reliable predictors of adverse outcome in SCI patients. These findings begin to challenge the paradigm of utilizing derangements in vital signs (traditional SIRS criteria and qSOFA score) to identify and risk stratify SCI patients with serious infections. Not only may delayed diagnosis lead to significant morbidity within this population, but treating based solely on the presence of aberrant vital signs can cause added harm through unnecessary hospitalizations and antibiotic exposure. Instead, our findings suggest that measures of end-organ dysfunction, such as SOFA score, may be more suited towards differentiating and prognosticating SCI patients harboring life-threatening infections. Future studies should evaluate the relationship between SOFA score and adverse outcomes from other types of infections that this population may be prone to.

We sought to use statistical methods in a fashion that would model the relationship between clinical variables and outcomes as accurately as possible. The utilization of piecewise linear spline functions with logistic regression permitted assessment of non-linear effects (age and SOFA score) on outcome that would have not been achievable with subgroup analysis or other methods. Thus, one of the strengths of our model is that clinical factors can be weighed appropriately in

estimating risk for each patient. Regarding the model itself, the Brier score is indicative of its good overall performance, while the c-index reflects the effective ability of the model to distinguish patients that will have a complicated outcome. Nearly identical corresponding values were generated during internal validation, which suggests slight overfitting of our predictive model. Additionally, the excellent calibration of the model is demonstrated in Fig. 2 by a calibration line that aligns very closely to the 45° reference line (perfect calibration).

Our study has several limitations. First, our study was conducted using data collected from a single center and internally validated. Therefore, our model may not be generalizable to SCI patient populations at other centers. Second, we relied upon ICD-9-CM discharge diagnosis codes to identify patients with SCI and UTI. There are no exact criteria for the diagnosis of UTI in individuals with SCI, and symptom-based diagnosis is challenging due to neurological injury. Due to the absence of singular symptoms and findings with both good sensitivity and specificity, the diagnosis of UTI often depends on a case-by-case, comprehensive clinical assessment.²² As a result, utilizing ICD-9-CM diagnosis coding may capture a more realistic UTI cohort and reflect true clinical practice and its uncertainty. Under-coding for these conditions could have resulted in missed cases and potential selection bias. Third, significant factors identified in our study cannot be used to predict 30-day mortality due to UTI in isolation, but rather as part of a composite complicated outcome only as we have defined it. Likewise, both SOFA and qSOFA were originally developed to predict in-hospital mortality in patients with sepsis and not the composite complicated outcome we have studied. Another limitation of our study was that we could only collect data on a limited number of clinical predictors. It is possible that other potentially significant variables were not identified for inclusion in our analysis. For example, degree of urodynamic dysfunction and frequency, technique, and duration of urinary catheterization are plausible risk factors for UTI, but this data was not captured in our retrospective study.^{7,23}

Conclusion

Female sex, urinary culture pathogen, and SOFA score appear to be predictors for a composite complicated outcome in a simple clinical risk model developed for patients with chronic SCI hospitalized with UTI. Our findings challenge the use of SIRS criteria and the presence of hypotension to predict adverse outcomes from

UTI in this unique patient population. Our clinical risk model demonstrated good overall performance in predicting composite adverse outcomes in our population of chronic SCI patients. Future research should focus on external validation of this model in separate patient populations at multiple centers and the identification of novel predictors for adverse outcomes in SCI patients with UTI and other severe infections.

Disclaimer statements

Contributors None.

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