Risk Factors and Consequences of Postoperative Urinary Tract Infections in Patients with Traumatic Cervical Cord Injury: A Retrospective Analysis

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Abstract:

Introduction: There is a lack of research on the relationship between cervical spinal cord injury (SCI) surgery and symptomatic urinary tract infections (UTIs); hence, this study seeks to fill this critical knowledge gap in postoperative care. This study aims to identify the risk factors for UTIs in patients with traumatic cervical SCI.

Methods: We retrospectively analyzed 187 patients (mean age: 68 years) who underwent cervical SCI surgery between 2017 and 2021. Patients were categorized into UTI and non-UTI groups. Patients with recurrent UTIs were defined as the multiple-UTI group. Preoperative risk factors, including prognostic nutritional index (PNI; 10×serum albumin [g/dL]+0.005 ×total lymphocyte count [/μL]), were assessed.

Results: Among 187 patients, 99 (52.9%) experienced a UTI within 90 days postoperatively. The majority of patients in the UTI group, that is, 92 patients (92.9%), had an indwelling catheter as urinary management at the time of the UTI. The UTI group faced higher rates of cardiopulmonary dysfunction, bacteremia, longer hospital stays, and increased medical costs. Multiple UTIs were associated with worse outcomes, including increased complications, longer hospital stays, and higher medical costs. PNI at 3 weeks and 4 weeks postoperatively in the multiple-UTI group was significantly lower than in the single-UTI and non-UTI groups. The American Spinal Injury Association impairment scale grade at admission was independently linked to initial UTI occurrence within 90 days after surgery when adjusting for confounding variables.

Conclusions: We found that 52.9% of patients experienced UTIs within 90 days postoperatively. The risk factors for UTI occurrence included the severity of paralysis, indwelling catheter, and poor improvement in the perioperative nutritional status. Early interventions with intermittent catheterization, appropriate antibiotics, and nutrition might be suggested for patients with severe cervical SCI and malnutrition.

Keywords:

perioperative complications, urinary tract infection, prognostic nutritional index, spinal cord injury, risk factor

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Introduction

Traumatic spinal cord injury (SCI) is a profound debilitating condition that disrupts sensory and motor functions[1]. Urinary tract infections (UTIs) are a common, yet distressing complication following cervical SCI surgery[2,3]. These infections not only compromise patient's recovery, but also pose significant healthcare challenges.

UTIs after SCI surgery are a major perioperative complication with a reported rate of 8%-31% depending on the surgical indication or specific spinal disorder[3,4]. These infections not only affect the quality of life of patients, but also prolong hospital stays, resulting in an increased burden on healthcare systems[5,6]. Risk factors for symptomatic UTIs in patients with SCI surgery include vesicoureteral reflux associated with lower urinary tract dysfunction[7], urinary management methods[8,9], and the location and severity of the SCI, including cervical SCIs and an impairment rated at scale C or higher on the American Spinal Injury Association (ASIA) impairment scale[10-12]. Despite the recognized association between SCI surgeries and UTIs, understanding of the explicit risk factors remains limited, necessitating a comprehensive investigation.

To our knowledge, there have been little reports on the association between cervical SCI surgery and symptomatic UTIs. The purpose of this study is to elucidate the risk factors specifically for the development of UTIs in patients with cervical SCI surgery. This study seeks to elucidate these contributing factors and bridge the knowledge gap in this critical area of postoperative care.

Materials and Methods

Hypothesis

It is hypothesized that by comprehensively analyzing the patient characteristics, laboratory, surgical data, and other potential confounders, we can identify the major contributing factors and derive strategies to effectively reduce UTI occurrence in this population.

Institutional review board approval

This retrospective study was approved by the institutional review board of our hospital and adhered to the principles of the Declaration of Helsinki. The requirement for consent was waived by the institutional review board because of the retrospective design.

Study design and patients

We retrospectively reviewed 330 consecutive patients with traumatic SCI treated between April 2017 and June 2021 at our institution (Fig. 1). The inclusion criteria were as follows: (1) follow-up period ≥1 year; and (2) age ≥16 years. The exclusion criteria were as follows: (1) atlantoaxial, thoracic, or lumbar injury surgery (n=57); (2) conservative treatment (n=50); (3) ASIA impairment scale grade E at admission (n=25); (4) insufficient assessment of clinical data or blood sampling preoperatively (n=5); (5) neurological status not evaluated correctly due to disturbed consciousness (brain injury, congenital disease, or severe psychiatric disorder; n=2); (6) surgery at other hospitals (n=2); and (7) exacerbation of cervical myelopathy (n=2). Finally, 187 patients with cervical SCI who underwent posterior fusion surgery were enrolled (158 men, 29 women; mean age 67.9 years) (Table 1).

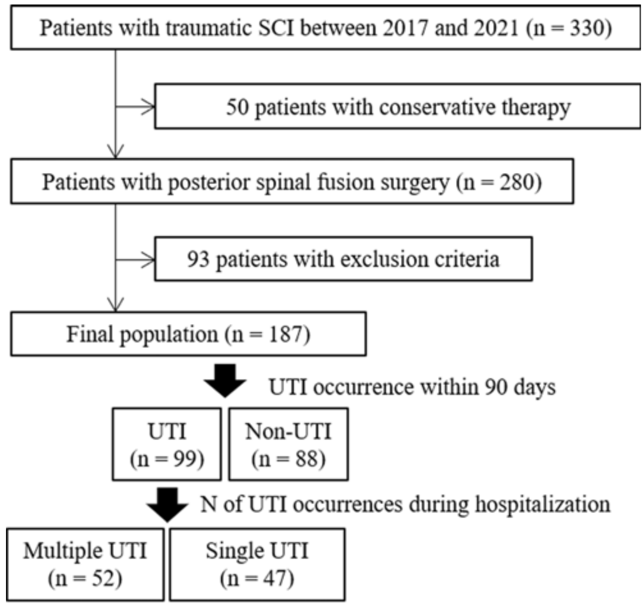

Figure 1. Study design.

Variables, data sources, and bias

The patient characteristics obtained from the medical records included sex, age, type of paralysis, time from injury to surgery, motor score, ASIA impairment scale grade, body weight, body mass index (BMI), alcohol consumption, smoking, lesion level, causes of injury, presence of comorbidity injury, preoperative complications, medications, and urinary management at the time of the UTI. Neurological status was assessed using the ASIA impairment scale (grades A to E)[13]. Time from injury to surgery was defined as the number of hours between the date of injury and the surgery. Causes of injury were classified as falling at ground level, falling from high or low places, road traffic accidents, falling from stairs, and sports. Blood samples were evaluated upon admission. The estimated glomerular filtration rate (mL/min), serum albumin (g/dL), C-reactive protein (mg/dL), creatinine (mg/dL), hemoglobin A1c (%), white blood cell count (/μL), hemoglobin (g/dL), platelets (/μL), and total lymphocyte count (/μL) were measured. Serum albumin and total lymphocyte count were evaluated preoperatively, 3 days, 1 week, 2 weeks, 3 weeks, and 4 weeks postoperatively. The following formula was used to calculate the prognostic nutritional index (PNI): 0.005×total lymphocyte count (/μL)+10×serum albumin (g/dL)[14]. Anesthesiologists estimated the general preoperative status using the American

Table 1. Comparison of the Baseline Data between the UTI and Non-UTI Groups.

Variable	UTI group n=99	Non-UTI group n=88	P-value
Male sex	89 (89.9%)	69 (78.4%)	0.030*
Age (years)	68.5±13.6	67.3±15.0	0.565
Type of paralysis			0.456
Tetraplegia	98 (99.0%)	86 (97.7%)	
Paraplegia	1 (1.0%)	2 (2.3%)	
Time from injury to surgery (hours)	32.9±79.4	40.0±94.1	0.609
Motor score at admission	29.1±25.5	47.2±33.1	<0.001*
ASIA impairment scale at admission			0.005*
A	27 (27.3%)	14 (15.9%)	
B	13 (13.1%)	8 (9.1%)	
C	38 (38.4%)	26 (29.5%)	
D	21 (21.2%)	40 (45.5%)	
Body weight (kg)	66.4±14.2	62.8±15.4	0.095
Body mass index	23.8±4.0	23.5±4.6	0.555
Alcohol consumption	42 (42.2%)	38 (43.2%)	0.917
Smoking	25 (25.3%)	14 (15.9%)	0.116
Lesion level			0.063
C3/4	45 (45.5%)	27 (30.7%)	
C4/5	22 (22.2%)	15 (17.0%)	
C5/6	15 (15.2%)	27 (30.7%)	
C6/7	14 (14.1%)	15 (17.0%)	
C7/T1	3 (3.0%)	4 (4.5%)	
Causes of injury			0.300
Falling at ground level	40 (40.4%)	31 (35.2%)	
Falling from high places	19 (19.2%)	18 (20.5%)	
Road traffic or traumatic accidents	13 (13.1%)	20 (22.7%)	
Falling from stairs	12 (12.1%)	13 (14.8%)	
Falling from low places	9 (9.1%)	3 (3.4%)	
Sports	6 (6.1%)	3 (3.4%)	
Comorbid injury	12 (12.1%)	10 (11.4%)	0.872

Values expressed as mean±SD or number (percentage). *Statistically significant difference.
UTI, urinary tract infection

Society of Anesthesiologists (ASA) classification. Surgical data, including the number of fusion levels, length of surgery, and estimated blood loss, were obtained from anesthetic and operative records.

Definition of UTI and clinical outcomes

The occurrence of non-neurological complications (not present before SCI surgery) during the acute phase of hospitalization was a primary dependent variable. In this study, symptomatic UTI is defined as a condition diagnosed as infected based on urinalysis or urine culture, accompanied by the presence of fever[15]. One of the perioperative complications was the occurrence of symptomatic UTI within 90 days postoperatively. Among patients with symptomatic UTI within 90 days postoperatively, patients who developed another symptomatic UTI during hospitalization were categorized into the multiple-UTI group (Fig. 1). Other perioperative complications included mortality, ventilator management, surgical site infection (SSI), pneumonia, transfusion, cardiopulmonary dysfunction, delirium, deep venous thrombosis (DVT), and pulmonary embolism within 30 days. We also added bacteremia during hospitalization as one of the perioperative complications. The diagnosis of infectious complications was defined based on the Centers for Disease Control and Prevention[15]. For the diagnosis of SSI, pneumonia, or bacteremia, microbiological guidelines state that bacteria must be linked to symptoms of surgical wound, respiratory infection, and/or systemic symptoms (fever, general discomfort). The postoperative occurrence of symptomatic respiratory failure, pleural effusion, pulmonary edema, or acute respiratory disorder was defined as a cardiopulmonary dysfunction[16]. The confusion assessment method was used to diagnose the occurrence of delirium based on medical records[17]. The perioperative complications were confirmed by attending surgeons or other medical personnel. We performed subgroup analyses of PNI values for each complication.

The secondary dependent variable was the cost of the acute-phase hospitalization period (within 90 days post-surgery). Medical fee data were used to extract all inpatient medical costs for the SCI surgery. The total medical expenses included surgical, hospital, and examination costs, as

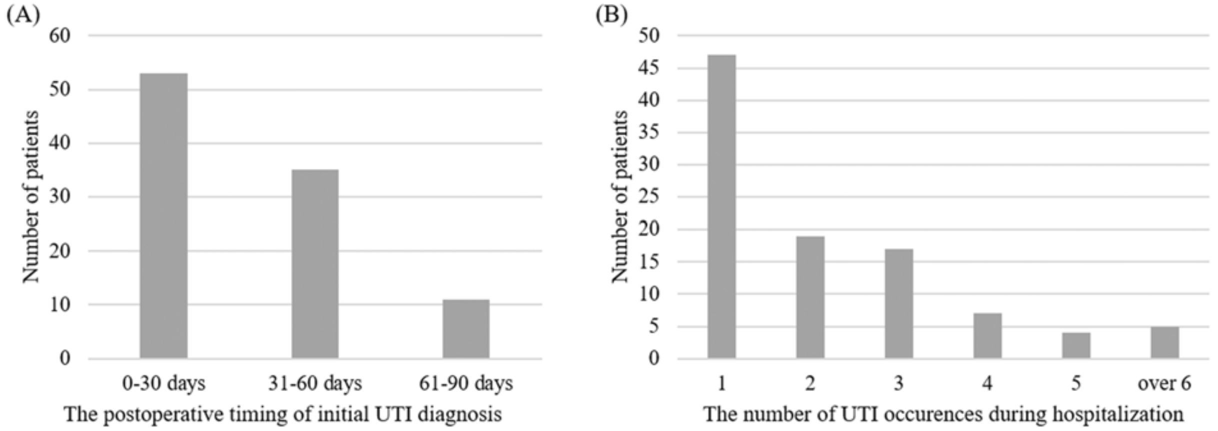

Figure 2. Timing and total number of UTI occurrence.
(A) Postoperative timing of the initial UTI diagnosis. (B) Number of UTI occurrences during hospitalization.
UTI=urinary tract infection

well as medical management or physical therapy costs. The tertiary dependent variables were motor score at discharge, rate of discharge to home, length of hospital stay, ASIA impairment scale grade at discharge, urinary management at discharge, and duration of indwelling catheterization.

Perioperative and urinary managements

During the study period, we continued early surgery for patients with SCI who required it, whenever possible. Early rehabilitation intervention from the day after the surgery was performed in the hospital. Following cervical SCI surgery, the acute phase represents the juncture at which preliminary interventions for SCI are implemented. For the dual purposes of ensuring patient immobilization and fluid management, a urethral catheter is strategically placed. Once a patient exhibits systemic stabilization, a detailed consultation is initiated with the urology department. The feasibility of extracting the indwelling urethral catheter hinges upon urodynamic study outcomes and upper limb functional assessments. If long-term urinary management with a urethral catheter is necessary, transitioning to a suprapubic bladder fistula catheter placement is considered.

Statistical analysis

The categorical variables were expressed as absolute numbers and percentages and analyzed with Fisher's exact tests or Chi-squared tests, as appropriate. We used the Shapiro-Wilk test to determine whether continuous variables were normally or non-normally distributed. Continuous variables with normal distributions were expressed as means±standard deviations and analyzed with unpaired *t*-tests. One-way analysis of variance, followed by Tukey post-hoc and Chi-squared tests, was used to detect between-group differences. The risk factors of UTI occurrence were examined with multivariate logistic regression analysis. Statistical analyses were performed using SPSS Version 26.0 (IBM, Armonk, NY, USA). P values of <0.05 were considered significant.

Results

Among 187 patients (Fig. 1), 99 (UTI group; 52.9%) experienced UTI within 90 days postoperatively. In the UTI group, the timing of the initial UTI diagnosis was up to 30 days postoperatively in 53 patients, 31-60 days postoperatively in 35 patients, and 61-90 days in 11 patients (Fig. 2A). The baseline, laboratory, and surgical data in the UTI and non-UTI groups are shown in Table 1, 2, respectively. Patients in the UTI group had a significantly lower motor score at admission (P<0.001) compared with those in the non-UTI group. The UTI group had a significantly higher proportion of cases involving male sex (P=0.030) and ASIA impairment scale grades A to C upon admission (P=0.005) compared with the non-UTI group. There was no significant difference found in the PNI and ASA classification scores between both groups (Table 2). The majority of patients in the UTI group, that is, 92 patients (92.9%), had an indwelling catheter as urinary management at the time of the UTI.

UTI risk factor analysis

After controlling for relevant confounding variables, including sex, age, ASIA impairment scale grade at admission, BMI, lesion level, PNI, and ASA classification score, we found that an ASIA impairment scale at admission (1 grade-difference; odds ratio, 1.522; 95% confidence interval, 1.161-1.994; P=0.002) was independently associated with the initial UTI occurrence within 90 days postoperatively.

Differences in the clinical outcomes between the UTI and non-UTI groups

The clinical outcomes in the UTI and non-UTI groups are shown in Table 3. In the analysis of the perioperative complications, the UTI group had significantly higher rates of cardiopulmonary dysfunction and bacteremia than the non-UTI group (P=0.018 and P=0.009, respectively). The UTI group had a significantly lower motor score at discharge (P=0.018), longer length of hospital stay (P<0.001), and longer

Table 2. Comparison of the Baseline, Laboratory, and Surgical Data between the UTI and Non-UTI Groups.

Variable	UTI group n=99	Non-UTI group n=88	P-value
Preoperative complications			
Hypertension	48 (48.5%)	34 (38.6%)	0.176
Diabetes mellitus	21 (21.2%)	16 (18.2%)	0.604
History of cerebral stroke	2 (2.0%)	6 (6.8%)	0.104
Chronic renal dysfunction	27 (27.3%)	14 (15.9%)	0.061
Current medication			
Steroid	0 (0%)	2 (2.3%)	0.220
Laboratory data at admission			
Estimated glomerular filtration rate (mL/min)	74.2±23.3	76.8±21.0	0.426
Serum albumin (g/dL)	3.7±0.4	3.7±0.4	0.566
C-reactive protein (mg/dL)	1.1±3.8	1.0±2.2	0.862
Creatine (mg/dL)	0.9±0.3	0.8±0.5	0.618
Hemoglobin A1c (%)	5.9±0.6	5.9±0.8	0.766
White blood cell (/μL)	8921±2840	8719±2810	0.626
Lymphocyte count (/μL)	1031±404	1007±425	0.695
Prognostic nutritional index at admission	41.6±4.8	42.1±5.1	0.487
ASA classification score	2.5±0.6	2.5±0.5	0.392
Surgical factor			
Numbers of fusion levels	2.3±1.4	2.1±1.3	0.472
Length of surgery (min)	150±55	145±47	0.522
Estimated blood loss (mL)	200±260	222±266	0.566
Urinary management at the time of UTI			-
Spontaneous urination	5 (5.1%)	-	
Intermittent catheterization	2 (2.0%)	-	
Indwelling catheterization	92 (92.9%)	-	
Suprapubic catheter placement	0 (0%)	-	

Values expressed as mean±SD or number (percentage).
UTI, urinary tract infection; ASA, American Society of Anesthesiologists

duration of indwelling catheterization than the non-UTI group. The UTI group had significantly higher medical costs in the third month postoperatively (737 vs. 678 USD; P=0.019). There was no significant difference in the rates of urinary management at discharge between the UTI and non-UTI groups (P=0.067).

Subgroup analysis of the PNI between groups with and without complications

The results of the subgroup analysis of the PNI between the groups with and without complications are shown in Table 4. The pneumonia, cardiopulmonary dysfunction, and DVT groups had significantly lower PNI values at admission compared to the non-complication groups (P<0.001, P<0.001, and P=0.028, respectively).

Differences in the clinical data in the multiple-UTI, single-UTI, and non-UTI groups

There were 52, 47, and 88 patients in the multiple-UTI, single-UTI, and non-UTI groups, respectively (Fig. 1 and Table 5). Among the multiple-UTI group, 19 had two UTIs; 17 had three UTIs; and 16 had four or more UTIs (Fig. 2B). Regarding the baseline data, significant differences in the motor score at admission (multiple-UTI: single-UTI: non-UTI groups=21.0: 38.1: 47.2, P<0.001) and ASIA impairment scale at admission (P<0.001) were found between the groups. Regarding perioperative complications, the prevalence of cardiopulmonary dysfunction (36.5%: 21.3%: 14.8%, P=0.011) and bacteremia (13.5%: 6.4%: 1.1%, P=0.006) was higher in the multiple-UTI group than in the single-UTI and non-UTI groups. The motor score at discharge (47.8: 69.7: 69.9, P<0.001) and the rates of discharge to home (38.5%: 57.4%: 60.2%, P=0.036) were lower in the multiple-UTI group than in the single-UTI and non-UTI groups. The length of hospital stay was longer in the multiple-UTI group than in the single and non-UTI groups (255 days: 177 days: 146 days, P<0.001). The medical costs at the third month postoperatively were higher in the multiple-UTI group than in the non-UTI group (755 vs. 678 USD; P=0.013). The ASIA impairment scale at discharge improved in all groups compared with that at admission, but significant differences in the ASIA impairment scale at discharge were found between groups (P<0.001). There was a significant difference in urinary management at discharge between groups (P=0.006). The duration of indwelling catheterization was longer in the multiple-UTI group than in the single and non-UTI groups (185 days: 97 days: 85 days, P<0.001). There was no significant difference in the PNI at

Table 3. Comparison of the Clinical Outcomes and Urinary Management between the UTI and Non-UTI Groups.

Variable	UTI group n=99	Non-UTI group n=88	P-value
Perioperative complications			
Mortality	0 (0%)	0 (0%)	-
Ventilator management	7 (7.1%)	2 (2.3%)	0.116
Surgical site infection	1 (1.0%)	2 (2.3%)	0.456
Pneumonia	14 (14.1%)	16 (18.2%)	0.452
Transfusion	21 (21.2%)	13 (14.8%)	0.254
Cardiopulmonary dysfunction	29 (29.3%)	13 (14.8%)	0.018*
Delirium	17 (17.2%)	12 (13.6%)	0.505
Deep venous thrombosis	43 (43.4%)	30 (34.1%)	0.191
Pulmonary embolism	0 (0%)	0 (0%)	-
Bacteremia	10 (10.1%)	1 (1.1%)	0.009*
Motor score at discharge	58.2±32.2	69.9±34.6	0.018*
Discharge to home	47 (47.5%)	53 (60.2%)	0.081
Length of hospital stay (days)	218±138	146±124	<0.001*
Medical costs (USD)			
First month after admission (A; n=178)	2567±619	2587±805	0.845
First 2 months after admission (B, n=153)	3390±672	3411±858	0.865
First 3 months after admission (C, n=133)	4175±738	4124±946	0.725
Second month (B–A; n=153)	794±185	758±219	0.269
Third month (C–B; n=133)	732±127	678±130	0.019*
ASIA impairment scale at discharge			0.201
A	14 (14.1%)	7 (8.0%)	
B	5 (5.1%)	6 (6.8%)	
C	24 (24.2%)	13 (14.8%)	
D	52 (52.5%)	55 (62.5%)	
E	4 (4.0%)	7 (8.0%)	
Urinary management at discharge			0.067
Spontaneous urination	43 (43.4%)	52 (59.1%)	
Intermittent catheterization	13 (13.1%)	6 (6.8%)	
Indwelling catheterization	42 (42.4%)	27 (30.7%)	
Suprapubic catheter placement	1 (1.0%)	3 (3.4%)	
Duration of indwelling catheterization (days)	143±124	85±118	0.001*

Values expressed as mean±SD or number (percentage). *Statistically significant difference.
UTI, urinary tract infection

admission between groups (P=0.083). However, the PNI at 3 weeks and 4 weeks postoperatively in the multiple-UTI group was significantly lower than in the single-UTI and non-UTI groups (P<0.001 and P<0.001, respectively; Fig. 3).

Discussion

In our study encompassing 187 patients, we found that 52.9% experienced a UTI within 90 days following surgery. As previously reported[10,12], the ASIA impairment scale grades A to C at admission were independently correlated with the initial UTI occurrence within 90 days postoperatively after controlling for confounding variables, highlighting the need for targeted interventions for patients at a higher risk. Our results indicated that the UTI group encountered more perioperative complications, specifically cardiopulmonary dysfunction and bacteremia, alongside a lower motor score at discharge, a longer hospital stay, and higher medical costs. This underscores the broader clinical implications of UTIs following surgery. Furthermore, on a subgroup analysis, multiple UTIs were associated with poor improvement in nutritional status, longer duration of indwelling catheterization, more severe complications, extended hospital stays, and increased costs.

Risk factors for UTI after SCI surgery

Predisposing elements contributing to symptomatic UTIs in individuals with SCIs encompass the phenomenon of a vesicoureteral reflux concomitant with lower urinary tract dysfunction[7], urinary management methods[8,9], cervical SCIs, and a disability scored at ASIA scale grade C or above[10-12]. Due to bladder and bowel dysfunction caused by the SCI, vesicoureteral reflux can occur, leading to a higher incidence of UTIs[7]. Compared to patients who perform clean intermittent catheterization (19%), those with indwelling urinary

Table 4. Subgroup Analysis of the Prognostic Nutritional Index at Admission between Groups with and without Complications.

Variable (subgroup analysis)	Pneumonia group n=30	Non-pneumonia group n=157	P-value
Prognostic nutritional index at admission	38.0±5.2	42.6±4.6	<0.001*
Variable (subgroup analysis)	Cardiopulmonary dysfunction group n=42	Non-cardiopulmonary dysfunction group n=145	P-value
Prognostic nutritional index at admission	38.9±4.6	42.7±4.7	<0.001*
Variable (subgroup analysis)	Delirium group n=29	Non-delirium group n=158	P-value
Prognostic nutritional index at admission	40.5±4.4	42.1±5.0	0.081
Variable (subgroup analysis)	DVT group n=73	Non-DVT group n=114	P-value
Prognostic nutritional index at admission	40.9±4.7	42.5±5.0	0.028*

Values expressed as mean±SD or number (percentage). *Statistically significant difference.
DVT, deep venous thrombosis

catheters significantly have a higher incidence of UTIs (81%)[8], which is consistent with this study. Avoiding the long-term use of indwelling catheters and adopting intermittent catheterization are specifically recommended. However, in cases with cervical SCI, where self-catheterization is challenging, the long-term use of indwelling urinary catheters may be unavoidable. Future research should focus on evaluating the effectiveness of these urinary management methods in detail and establishing the optimal strategies for UTI prevention. Consistent with previous studies, the significant factors identified as affecting UTIs in this study were lower motor scores at admission and ASIA impairment scale grades A to C (Table 1). Malnutrition is reported as one of the risk factors for UTIs after posterior spinal fusion surgery[18]. Kidney transplant recipients with prolonged postoperative malnutrition had an increased risk of UTI[19]. The PNI, which is calculated using serum albumin levels and total lymphocyte count, is a widely utilized tool for assessing the nutritional status across numerous fields[14,20]. In a study by Acarbas et al., a lower preoperative PNI score (a cutoff value of 47.7) was found to be a significant risk factor for perioperative complications in patients undergoing spinal surgery[20]. This is the first study to reveal that malnutrition persists when multiple UTIs occur after cervical SCI surgery. We found that lower PNI values are associated not only with a higher risk of UTIs, but also with an increased incidence of other complications, such as pneumonia, cardiopulmonary dysfunction, and DVT in patients with cervical SCI. Furthermore, we hypothesized that nutritional assessment using the PNI score and nutritional intervention may have the potential to reduce the risk of perioperative complications, including UTIs.

Impact of UTI on clinical outcomes

The UTI rate after cervical SCI surgery was 52.9%, which was in the high range compared to previous studies (8%-31%)[3,4,16,21-24]. The reason for this was that most patients had risk factors for UTI, such as preoperative neurological injury, cervical SCI, or longer duration of indwelling catheterization[8,10,11]. Postoperative UTI can result in an increased risk of perioperative infection complications, including SSI or systemic sepsis, higher morbidity and mortality, longer length of hospital stay, and greater medical costs[5,6,25,26]. Consistent with previous studies, patients with UTIs had increased perioperative complications, including cardiopulmonary dysfunction and bacteremia, a lower motor score at discharge, a longer hospital stay, and higher medical costs (Table 3). Furthermore, as the occurrence of recurrent UTIs negatively impacted clinical outcomes, we need to consider the abovementioned preventive managements for recurrent UTIs. However, in addition to UTI occurrences, the severity of paralysis and other complications significantly contribute to longer hospital stays and higher medical costs. Moreover, the length of hospital stays and associated costs can vary considerably depending on whether patients are discharged home or transferred to another facility once their general condition stabilizes.

Limitations

There are several limitations of this study. First, our reliance on single-center retrospective data and a relatively small sample size may restrict our capacity to infer causative associations. The small sample size and the inability to adjust for key factors, such as the severity of paralysis, and other complications limit the generalizability and robustness of our findings. Second, our study encompassed an array of surgical methods using a posterior approach for different fracture and dislocation types, potentially introducing variability in perioperative complication rates depending on the specific surgical procedure or condition. Lastly, while we took measures to minimize the selection bias by recruiting patients consecutively, the possibility of its presence cannot

Table 5. Comparison of the Baseline, Clinical Outcomes, and Urinary Management between the Subgroups.

Variable	Multiple-UTI n=52	Single-UTI n=47	Non-UTI n=88	P-value (ANOVA/ Chi-square)	P-value (Tukey)
Male sex	48 (92.3%)	41 (87.2%)	69 (78.4%)	0.075	-
Age (years)	69.3±14.7	67.5±12.3	67.3±15.0	0.697	-
Time from injury to surgery (h)	18.6±37.6	49.0±107.2	40.0±94.1	0.236	-
Motor score at admission	21.0±20.4	38.1±27.8	47.2±33.1	<0.001*	*; a, b
ASIA impairment scale at admission				<0.001*	-
A	20 (38.5%)	7 (14.9%)	14 (15.9%)		
B	10 (19.2%)	3 (6.4%)	8 (9.1%)		
C	18 (34.6%)	20 (42.6%)	26 (29.5%)		
D	4 (7.7%)	17 (36.2%)	40 (45.5%)		
Body weight (kg)	67.7±10.9	64.9±17.2	62.8±15.4	0.161	-
Body mass index	24.4±3.4	23.2±4.5	23.5±4.6	0.336	-
Prognostic nutritional index at admission	40.6±5.3	42.7±4.0	42.1±5.1	0.083	-
ASA classification score	2.6±0.6	2.5±0.5	2.5±0.5	0.579	-
Perioperative complications					
Cardiopulmonary dysfunction	19 (36.5%)	10 (21.3%)	13 (14.8%)	0.011*	-
Bacteremia	7 (13.5%)	3 (6.4%)	1 (1.1%)	0.006*	-
Motor score at discharge	47.8±31.6	69.7±29.2	69.9±34.6	<0.001*	*; a, b
Discharge to home	20 (38.5%)	27 (57.4%)	53 (60.2%)	0.036*	-
Length of hospital stay (days)	255±153	177±108	146±124	<0.001*	*; a, b
Medical costs (USD)					
First month after ad. (A; n=178)	2704±707	2407±457	2587±805	0.117	-
Second month (B–A; n=153)	814±226	768±116	758±219	0.305	-
Third month (C–B; n=133)	755±151	702±84	678±130	0.013*	*; b
ASIA impairment scale at discharge				0.001*	-
A	11 (21.2%)	3 (6.4%)	7 (8.0%)		
B	1 (1.9%)	4 (8.5%)	6 (6.8%)		
C	19 (36.5%)	5 (10.6%)	13 (14.8%)		
D	20 (38.5%)	32 (68.1%)	55 (62.5%)		
E	1 (1.9%)	3 (6.4%)	7 (8.0%)		
Urinary management at discharge				0.006*	-
Spontaneous urination	15 (28.8%)	28 (59.6%)	52 (59.1%)		
Intermittent catheterization	8 (15.4%)	5 (10.6%)	6 (6.8%)		
Indwelling catheterization	28 (53.8%)	14 (29.8%)	27 (30.7%)		
Suprapubic catheter placement	1 (1.9%)	0 (0%)	3 (3.4%)		
Duration of indwelling catheterization (days)	185±139	97±83	85±118	<0.001*	*; a, b

Values expressed as mean±SD or number (percentage). Multiple comparison a: Multi- vs. Single-UTI; b: Multi- vs. Non-UTI; and c: Single- vs. Non-UTI. *Statistically significant difference.
UTI, urinary tract infection

be completely eliminated in this study. In summary, our findings contribute to a better understanding of the postoperative UTI risk factors in patients with cervical SCIs. However, a well-designed prospective multi-center study with a large sample size is necessary to refine these risk factors and develop effective preventive measures. Our findings might have significant implications for improving patient outcomes and reducing healthcare costs in this patient population.

Conclusions

We found that 52.9% of patients experienced UTIs within 90 days postoperatively. This study identified the potential risk factors for UTIs after cervical SCI surgery, including longer duration of indwelling catheterization, lower motor scores at admission, poor improvement in perioperative nutritional status, and ASIA impairment scale grades A to C. This is the first study to reveal that malnutrition persists when multiple UTIs occur after cervical SCI surgery. In order to prevent recurrent UTIs, the proposed strategies not only include early initiation of antibiotic treatment for fever in patients with severe SCIs, we also hypothesize that early interventions with intermittent catheterization and nutrition may have the potential to reduce the risk of perioperative complications, including UTIs.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

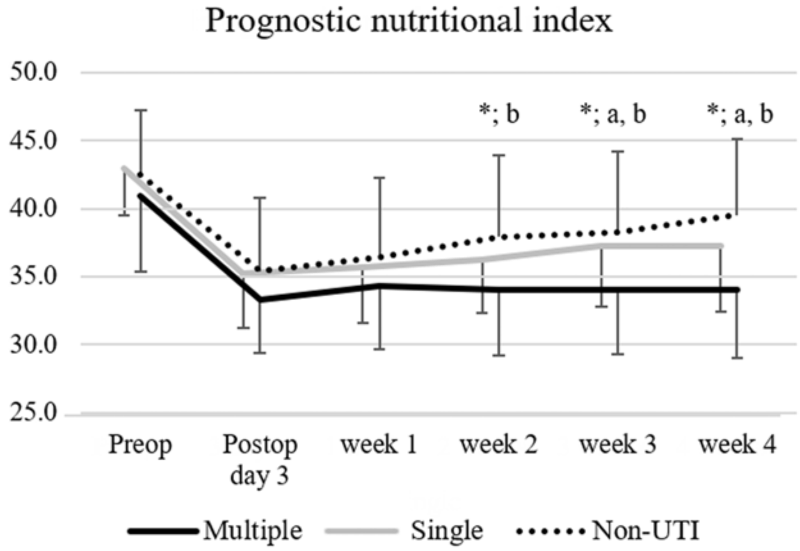

Figure 3. Perioperative change in a prognostic nutritional index.
Multiple comparison: (a) multi- vs. single-UTI, (b) multi- vs. non-UTI, and (c) single- vs. non-UTI. *Statistically significant difference.
UTI=urinary tract infection

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Ethical Approval: The study protocol was approved by the Institutional Review Board of Hokkaido Spinal Cord Injury Center (research approval no. 22-73).

Informed Consent: The requirement for consent was waived by the Institutional Review Board because of the retrospective design.

Availability of Data and Material: The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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