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Research article

# An unresolved relationship: the relationship between lesion severity and neurogenic bladder in patients with spinal cord injury

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**Objectives:** We aimed to investigate the relationship between the severity of the spinal lesion and urodynamic findings, bladder drainage method at discharge, and incidence of renal calculi in patients with spinal cord injury (SCI).

**Studydesign:** Retrospective.

**Setting:** In-patient rehabilitation unit of a tertiary research hospital.

**Methods:** A total of 131 patients who were admitted to our clinic with a diagnosis of SCI and placed into a rehabilitation program were included in the study. The severity of the lesion was determined according to the American Spinal Injury Association Impairment Scale (AIS). We evaluated the relationship between the severity of the lesion and the detrusor hyperactivity and compliance as determined by urodynamic investigation, the bladder drainage method used at discharge, and the renal calculi rate as determined by ultrasonography.

**Results:** While no difference was found between the patients with complete and incomplete injuries in terms of age, sex, disease duration, detrusor hyperactivity and compliance, the bladder drainage method was found to show a significant change according to the severity of the lesion. None of the patients were found to have hydronephrosis and the rate of renal calculi showed no statistically significant difference according to the severity of the lesion.

**Conclusions:** We concluded that urodynamic examination is required in each patient with SCI as the severity of the lesion is not sufficient to determine the bladder type, and patients with complete and incomplete injuries should be monitored with the same sensitivity in terms of complications.

**Keywords:** Bladder management, Neurogenic bladder, Urodynamic examination, Spinal cord injury

## Introduction

Although mortality due to urological complications has decreased during the past decades, urinary tract complications have drawn attention as a significant cause of morbidity and decreased life quality in patients with spinal cord injury (SCI). Urinary dysfunction is very common in this group of patients and approximately 81% report at least some degree of impaired bladder function within 1 year after injury.<sup>1</sup> Following a complete lesion at the suprasacral level, the development of detrusor

hyperactivity, classically after the spinal shock, is the most common finding.<sup>2</sup> However, it has been reported that somatic neurological findings are not always consistent with urodynamic findings.<sup>3-5</sup> The disorder may be overlooked, particularly in patients with incomplete injury. Clinicians may not be aware of the seriousness of urinary tract dysfunction in patients with incomplete injury, especially in those that are ambulatory, and life-threatening complications such as recurrent urinary tract infection, vesicoureteral reflux (VUR), hydronephrosis and renal failure may develop.<sup>6</sup> The correct evaluation of neurogenic bladder is therefore an important part of neurogenic bladder treatment for patients with SCI.

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There are only a few studies on the relationship between the severity of the injury and the bladder drainage method in the literature. Contradictory results have been obtained in these studies. Some suggest that the severity of the injury does not affect the bladder drainage method,<sup>1,7</sup> while others report that the bladder drainage method is related to whether the injury is complete or incomplete.<sup>8</sup>

The insufficient data in this matter indicates a necessity for new studies in this field. We therefore aimed to evaluate the relationship between the severity of the injury and the detrusor type, compliance, presence of bladder sensation, urinary tract ultrasonography (USG) findings and bladder drainage methods at discharge in a group of patients with SCI with a suprasacral level of complete and incomplete injury.

## Methods

The medical records of 236 patients with SCI who were admitted to our clinic and were placed into a rehabilitation program between January 2007 and October 2013 were evaluated. Patients who were clinically in the spinal shock period, pediatric patients, those with multiple levels of lesions in the spinal cord, or patients with multiple sclerosis were excluded from the study. A total of 131 patients who had SCI at the suprasacral level and whose urodynamic data could be accessed were included.

The sex, age, etiology of injury, and injury duration of the patients and the severity and level of the injury according to the "American Spinal Injury Association (ASIA) Impairment Scale" (AIS) were recorded. The patients were divided into two groups according to the severity of the lesion as complete (AIS A) and incomplete (AIS B-D). Approval from the ethics committee of the University was obtained for this study.

The urodynamic investigation records of the patients as performed by the Department of Urology were evaluated. Urodynamic examinations were performed using a standard procedure for all patients. Following full evacuation of the bladder, saline at room temperature was used to fill the bladder at a rate of 20 ml/minute. The study was ended if the patient expressed a strong urge to void, marked leakage developed, intravesical pressure exceeded 40 cmH<sub>2</sub>O, or there were signs of autonomic dysreflexia. The detrusor type, detrusor compliance and bladder fullness sensation were evaluated in the urodynamic records. Detrusor hyperactivity was defined as a nonvolitional increase in detrusor pressure of at least 15 cmH<sub>2</sub>O.<sup>9</sup> The detrusor type was classified as hyperactive or normoactive. Bladder compliance was defined as ratio of a change in bladder volume to the

associated change in intravesical pressure. Compliance  $\geq 20$  ml/cmH<sub>2</sub>O was accepted as normocompliance and  $< 20$  ml/cmH<sub>2</sub>O as hypocompliance.<sup>10</sup> Bladder fullness sensation was classified as "absent", "preserved" (same as it was before the trauma) or "partially preserved" (different in quality or magnitude).<sup>11</sup> Bladder drainage methods of the patients at discharge were divided into four groups as indwelling urethral catheter, clean intermittent catheterization (CIC), spontaneous voiding, and diapers/external catheter. The urinary system was also investigated with USG in all patients and the presence of renal calculi or hydronephrosis was recorded.

## Statistical evaluation

The Statistical Package for Social Sciences (SPSS) for Windows 20 (IBM Corp, Armonk, NY, USA) program was used for statistical evaluation. Normal distribution of the data was evaluated with the Kolmogorov-Smirnov test. The quantitative variables that displayed normal distribution were shown as mean  $\pm$  standard deviation and those that did not were presented as median (min-max). Categorical variables were stated as numbers and percentages. The *t*-test was used for independent samples of parametric distribution data and the Mann-Whitney *U* test was used for non-parametric distribution data in the comparison of 2 groups. The  $2 \times 2$   $\chi^2$  test and Fisher's definite  $\chi^2$  test were used for the comparison of categorical data. ANOVA was used for permanent data showing normal distribution and the Kruskal-Wallis H statistics were used for permanent data not showing normal distribution.

A P value  $< 0.05$  was accepted as statistically significant with 95% CI and 5% tolerance in statistical analyses.

## Results

The demographic and clinical characteristics of the patients included in our study are presented in Table 1. Lesion severity was complete in 85 (64.9%) and incomplete (AIS B-D) in 46 (35.1%) patients. No statistical difference was found between the patients with complete and incomplete injuries in terms of mean age, sex, and lesion severity.

The etiology of the injury was traumatic in 111 patients (84.7%) and non-traumatic in 20 patients (15.3%). Traffic accidents were the most common cause of injury. The etiology of the injuries has been summarized in Table 2.

Hyperactive detrusor rates and detrusor hypocompliance rates of the patients with complete and incomplete

**Table 1 Demographic characteristics of patients with complete and incomplete SCI**

	Complete SCI (n=85)	Incomplete SCI (n=46)	P-value
Age (year) (mean ± s.d.)	39.39 ± 13.10	43.61 ± 15.49	0.118
Duration of disease (months) (mean ± s.d.)	5.52 ± 8.26	7.93 ± 13.66	0.274
Sex, n (%)			
Female	28 (33.3)	13 (27.7)	0.559
Male	56 (66.7)	34 (72.3)	
Lesion level n, (%)			
Tetraplegia (C4-T1)	21 (25)	15 (31.9)	0.420
Paraplegia (T2-T12)	63 (75)	32 (68.1)	

SCI: spinal cord injury.

**Table 2 The reason of the spinal cord injuries of the patients**

	N	(%)
Traumatic spinal cord injury		
Traffic accident	56	50.5
Falling from height	36	32.4
Gunshot injury	8	7.2
Diving into shallow water	2	1.8
Other traumatic causes	9	8.1
Non-traumatic spinal cord injury		
Vascular reasons	5	25
Neoplasm	4	20
Degenerative reasons	4	20
Other non-traumatic reasons	6	30

lesions were similar. The bladder filling sensation of the patients differed according to the severity of the lesion. All patients in the group with "preserved" bladder filling sensation had incomplete injury. Protection rates of the bladder filling sensation of the patients according to the severity of the lesion are given in Table 3.

The bladder drainage method of the patients at discharge showed a difference according to the severity of the injury. While indwelling catheter rates were higher in patients with complete injury than in those with incomplete injury, the percentage of patients who used CIC was higher among those with incomplete injury.

There was no patient with spontaneous urination in the group with complete injury (Table 3).

While hydronephrosis was not found with USG in any of the patients, the percentage of patients with renal calculi did not show a statistically significant association with the severity of lesion (Table 4).

## Discussion

Conflicting data are available between lesion severity and neurogenic bladder and the bladder drainage method in patients with SCI. We evaluated the relationship between the severity of the injury and neurogenic bladder type, renal calculi ratio and bladder drainage methods at discharge in these patients. We found no relationship between lesion severity and the detrusor hyperactivity and compliance, but bladder filling sensation showed a difference according to the severity of the injury and the percentage of patients found to have renal calculi in the evaluation with USG showed no difference according to the lesion severity. In addition, it was observed that the bladder drainage method at discharge showed a difference according to the severity of the injury with a higher indwelling catheter percentage in patients with complete injury and the CIC percentage in incomplete injury patients. As far as we know, this study includes the largest number of patients in this regard.

**Table 3 Urodynamic findings and bladder drainage method in patients with SCI according to the severity of the lesion**

	Complete SCI (n = 85)	Incomplete SCI (n = 46)	P-value
Detrusor hyperactivity (yes) n, (%)	26 (30.6)	19 (41.3)	0.218
Detrusor hypocompliance (yes) n, (%)	46 (54.1)	26 (56.5)	0.792
Bladder filling sensation n, (%)			
absent	65 (76.5)	21 (45.7)	0.001*
preserved	–	16 (34.8)	
partially preserved	20 (23.5)	9 (19.6)	
Bladder drainage method n, (%)			
indwelling urethral catheter	61 (71.8)	14 (30.4)	0.001*
intermittent catheterization	22 (25.9)	19 (41.3)	
spontaneous voiding	–	10 (21.7)	
diaper/external catheterization	2 (2.4)	2 (6.5)	

SCI: spinal cord injury. \*P > 0.05.

**Table 4 Renal calculi incidence in patients with spinal cord injuries according to the severity of the lesion**

	Complete SCI (n = 85)	Incomplete SCI (n = 46)	P-value
Renal calculi n, (%)			
Yes	7 (8.2)	2 (4.3)	0.488
No	78 (91.8)	44 (95.7)	

SCI: spinal cord injury.

The micturition reflex is regulated at the S2–S4 level of the sacral spinal cord. However, it is known that voiding is not only through the local reflex arc and that bladder distention is transmitted to the central nervous system through the afferent fibers of the pelvic nerve coming from the rear root of the S2–4 segment, and that the detrusor contraction and sphincter relaxation are realized via the front roots of the pelvic and pudendal nerves as afferent fibers, leading to bladder drainage.<sup>12–15</sup>

Normal detrusor function is filling of the bladder without any change or with a small change in pressure. Detrusor hyperactivity is a urodynamic observation characterized by involuntary detrusor contractions during the filling phase which may be spontaneous or provoked.<sup>9</sup> After the spinal shock period, complete suprasacral injuries classically result in detrusor hyperactivity; the end result is an hyperactive, uninhibited bladder caused by disruption of central modulation of the detrusor and external sphincter muscle. However, previous investigators have noted an inexact correlation between somatic neurological findings and characteristic urodynamic findings.<sup>1,3–5,16,17</sup> It was shown with urodynamic evaluation that lower urinary system dysfunction may be present in patients who are neurologically intact in a study conducted on 44 patients with SCI with a thoracolumbar level lesion.<sup>18</sup> Another study on 64 patients with chronic SCI in an ambulatory state reported that a deterioration of bladder functions can be present with AIS D and AIS E and that detrusor hyperactivity is also important for ambulatory patients.<sup>19</sup> We observed no statistically significant difference between the patients with complete and incomplete injuries in terms of detrusor hyperactivity presence in patients with SCI in our study and this was consistent with other reports but we were able to demonstrate our results with a larger number of patients.

A number of factors may have caused the lack of a relationship between the severity of injury in the spinal cord and the type of neurogenic bladder. One of these is whether SCI is complete or incomplete and is determined according to the AIS scale. This scale evaluates the somatic nervous system including the motor and sensory functions, and does not evaluate the autonomic

nervous system. Autonomic nerve system innervation of the lower urinary tract can be evaluated with urodynamics and advanced electrophysiological tests.<sup>8</sup> Other factors include a somatic incomplete complete lesion becoming automatic incomplete or vice versa, presence of subclinical multiple lesions, degeneration occurring distal to the lesion, reorganization and decentralization, and the deterioration of the relationship between the bladder and somatic elements.<sup>3,8</sup>

Bladder compliance is the relationship between the volume changes in the bladder and the bladder detrusor pressure during filling cystometry. It is found by dividing the volume change inside the bladder into the pressure change detected in the bladder detrusor. The detrusor pressure should normally remain stable or not increase at all while the bladder is filling with urine. Hypocompliant bladders cannot hold this pressure, with the pressure increases to high levels as the bladder fills and potentially resulting in VUR.<sup>16</sup> Three mechanisms related to the decreased bladder compliance have been suggested. The first of these mechanisms is the neurogenic theory and is explained as muscle hypertrophy depending on nerve hyperreactivity.<sup>20</sup> The second mechanism is of myogenic origin where collagenous tissue takes the place of the muscles that cannot contract.<sup>21</sup> The third mechanism is the formation of the fibrosis in the bladder as a result of inactivation of the detrusor muscle.<sup>22</sup> Bladder compliance has been suggested to be independent of lesion level and whether the lesion is complete or incomplete and to decrease in time.<sup>23,24</sup> We found no relationship between the severity of the lesion and compliance and this was consistent with other studies.

The stretch receptors in the detrusor muscle are activated with the increase of bladder volume or detrusor contraction during bladder filling and thin myelinated pelvic afferent pelvic nerves fire. These impulses are transmitted to the sacral spinal cord, with some afferents directly being transmitted to the Onuf nucleus, some to Lissauer's tract, and some to the thoracolumbar spinal cord.<sup>11</sup> The filling sensation stemming from the lower urinary tract can be evaluated during the filling cystometry in humans. Some studies have reported that the bladder filling sensation can be preserved in patients

with incomplete injuries and suggested that it can be transmitted to the spinal cord with the hypogastric nerve. The presence of the bladder filling sensation in these patients may be useful in determining bladder drainage time.<sup>25</sup> The bladder sensation has been shown to be preserved in patients with SCI, although patients with normal bladder sensation were all in the incomplete group in our study. These findings are consistent with previous studies.<sup>11,26</sup> The treatment of neurogenic bladder is one of the most important components of the rehabilitation program for patients with SCI. The choice of bladder drainage method depends on many factors such as urodynamic examination results, age, sex, mobility, lesion level, educational level, and socioeconomic factors. CIC is the safest and most commonly used bladder drainage method at present due to its lower rate of urinary complications. There are only a few studies evaluating the relationship between the severity of the injury and the bladder emptying method in the literature.<sup>7,8</sup> Rapidi *et al.* found no difference between AIS A and AIS B patients in terms of neurogenic bladder type, compliance and bladder drainage method. However, they investigated the effect of partial somatosensory protection on urinary tract dysfunction and did not evaluate motor incomplete patients unlike our study.<sup>7</sup> The bladder drainage method was found to vary according to the severity of the injury in a study performed by Yıldız *et al.* on 49 patients with SCI. While the CIC and spontaneous voiding rate was higher in the incomplete group, spontaneous voiding was not achieved in the complete injury group and there was a high rate of indwelling catheters.<sup>8</sup> Similar results were obtained in our study as well. Indwelling urethral catheter implementation ranked first in patients with a complete lesion, and the CIC use and spontaneous voiding rate was found to be high in patients with an incomplete lesion. Various factors can be suggested as the reason of the higher indwelling urethral catheter rate in the complete group. After urodynamic studies were performed on patients with SCI, CIC was first choice as a bladder drainage method in our clinic. However, neurogenic bladder characteristics as well as the functional state and the patient's own preferences were taken into account when selecting the bladder drainage method. An indwelling catheter can be preferred in patients with tetraplegia due to the inadequate hand function to self-catheterize and the dependency on family members or caregivers to carry out the technique. However, this explanation does not seem plausible since there was no significant difference in terms of the number of patients with tetraplegia among patients with complete and incomplete injury in our study.

It has also been reported that females find CIC more distressing and uncomfortable than males. However, there was no significant difference between the groups in terms of the number of females and males. In interview studies performed in the United States of America, patients with SCI stated that the presence of a urine bag attached to an indwelling catheter was a serious handicap for them during their social activities.<sup>27</sup> Although there are no conducted interview studies in our country, our clinical observation is that patients with limited mobilization have limited resources to participate in social activities and mostly spend time at home and do not feel any discomfort with the presence of a urine bag. On the other hand, due to low income most patients who are not independently mobile cannot afford to have a caregiver, which forces them to use an indwelling catheter instead of CIC. Furthermore, the patients' refusal to use CIC could be due to many other factors such as psychological reasons, presence of pressure sores or educational status.

The SCI population has a high incidence of renal calculi, especially in the presence of VUR.<sup>16</sup> Other factors considered to be related to the calculi formation following SCI are hypercalcemia, advanced age, complete lesion, the presence of an indwelling catheter, urinary tract infection and immobilization.<sup>16,28</sup> It was suggested that new renal calculi develop in 7% of the patients and the most risky period is the first 3 months after the injury, in a study with 10 years of follow-up in patients with SCI.<sup>29</sup> Similar rates such as 6.5–8% were also reported in other studies.<sup>28,30</sup> The renal calculus rate was shown to be higher in patients with complete cord lesion in some studies focusing on the characteristics of the injury.<sup>31,32</sup> A positive association of the severity of injury and requiring instrumentation for bladder emptying with kidney stones was found after the first year post injury.<sup>29</sup> However, a few studies stated that whether the injury was complete was not related to calculi formation.<sup>5,33</sup> We found a renal calculi incidence of 8% in the complete injury group and 4% in the incomplete injury group. We did not find hydronephrosis in any of our patients, and there was no statistically significant relationship between lesion severity and renal calculi incidence. We believe that the reason for these results is our short follow-up period.

Our study has certain limitations. Our data were retrospectively obtained from the patient charts. In addition, our follow-up periods were short due to the rapid patient turnover of our clinic. Further studies with longer follow-up periods to be performed prospectively may eliminate the lack of data on this topic.

## Conclusion

Neurogenic bladder is not a problem that is only seen in patients with complete SCI. It can also be encountered together with severe complications in patients with incomplete injuries. Patients with both complete and incomplete SCI should be monitored with the same diligence regarding neurogenic bladder dysfunction and the necessary evaluations in addition to urodynamic examinations should be performed in patients with incomplete SCI in view of the complications that may develop. In addition, patients with complete SCI should be further encouraged to employ CIC applications such as bladder drainage.

## Disclaimer statements

**Contributors** SIA: collated and analysed the patients data and conceived the project. BS: reviewed the cases selected for inclusion and helped compile the manuscript. SAY: reviewed included cases. SNSC: helped compile the manuscript.

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**Conflicts of interest** All authors have read and approved the manuscript and we have no potential conflict of interest regarding this manuscript.

**Ethics approval** This study was approved by Baskent University Institutional Review Board (Project no: KA12/265).

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