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Original Article

Comparison of urodynamic findings in patients with suprasacral spinal cord injury according to the time of injury

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ABSTRACT

Objectives: This study aims to investigate the reflex bladder's occurrence according to urodynamic parameters in patients with suprasacral spinal cord injury (SCI) within one year after injury.

Patients and methods: Between May 2021 and July 2023, a total of 83 (57 males, 26 females; median age: 32 years; range, 19 to 64 years) suprasacral traumatic SCI patients within one year after injury were included in the study. The patients were divided into two groups as complete or incomplete SCI according to the American Spinal Cord Injury International Standards for Neurological Classification of SCI. Also, the patients were divided into two groups as ≤90 days or 91-365 days according to the duration between injury and urodynamics.

Results: Thirteen (37.1%) of 35 patients within 90 days after injury had detrusor overactivity (DO). During the ≤90 days period, the DO and detrusor-external sphincter dyssynergia (DSD) rates of incomplete suprasacral SCI patients were significantly higher than complete suprasacral SCI patients ($p<0.05$). Within three months after injury, although the median storage phase maximal detrusor pressure [Pdet (max)] of incomplete suprasacral SCI patients was significantly higher than complete suprasacral SCI patients ($p=0.007$), the Pdet (max) >40 cmH_2O rates were similar between complete and incomplete patients ($p=0.213$). The urodynamic parameters of patients with complete and incomplete suprasacral SCI were similar after three months of injury ($p>0.05$).

Conclusion: Although urodynamics investigation is recommended after spinal shock in SCI patients, detrusor reflex did not recover completely in most of suprasacral SCI patients within three months after injury in our study. The development of DO occurs significantly earlier in patients with incomplete suprasacral SCI than patients with complete suprasacral SCI.

Keywords: Detrusor overactivity, neurogenic bladder, spinal cord injury, urodynamics.

Neurogenic lower urinary tract dysfunction (NLUTD) is one of the common causes of morbidity and mortality in spinal cord injury (SCI) patients.[1] Therefore, the careful evaluation and treatment of NLUTD are the cornerstone in this patient population. Urodynamics is the only way to diagnose neurogenic bladder objectively with quantitative data, and optimal long-term clinical effectiveness can only be achieved with urodynamic guidance.[2]

The main goal of NLUTD treatment is to prevent upper urinary tract complications associated with neurogenic bladder.[3] Following the spinal shock period, detrusor overactivity (DO) and detrusor external sphincter dyssynergia (DESD) are seen in most of the patients with suprasacral SCI. High bladder storage pressure is the major risk factor for upper urinary tract detorsion in patients with suprasacral SCI.[4] However, the reflex bladder occurrence duration and the timing for performing initial urodynamic examination after SCI are unclear, since most of the urodynamic studies in the literature are related to the chronic period of SCI and urodynamic data are insufficient in the early period of SCI.[5] Spinal shock is well described for skeletal muscles innervated by the somatic nervous system, but information about the principles of reflection spinal shock to smooth

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musculature such as detrusor innervated by the autonomous nervous is insufficient. The end of spinal shock refers to the return of bulbocavernosus reflex or deep tendon reflex and often takes several days or weeks. However, the recovery of the detrusor reflex is slower than the somatic responses.[6,7] Urodynamics performed early after SCI may require repeating the investigation. Although urodynamics is a minimally invasive investigation, it carries risks of infection and bleeding. On the other hand; long-term persistence of the high intravesical pressures associated with DO can cause to vesicoureteral reflux, ureteral dilatation, hydronephrosis. Therefore, prompt detection and timely intervention of DO are critical.[8] Over time, the high intravesical pressures associated with DO and DSD cause upper urinary tract distortion.

In the present study, we aimed to investigate reflex bladder's occurrence by evaluating urodynamic parameters in suprasacral SCI patients within one year after injury.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at Ankara City Hospital , Department of Physical Medicine and Rehabilitation between May 2021 and July 2023. The medical records of 150 patients with traumatic SCI were initially screened. Patients with SCI within one year after injury whose neurological injury level above T12 according to the American Spinal Cord Injury International Standards for Neurological Classification of SCI (i.e., upper conus medullaris) and who had all out of spinal shock (i.e., the recovery of bulbocavernosus reflex or deep tendon reflex demonstrate the end of spinal shock) were included in the study. All patients included in the study received inpatient rehabilitation in the SCI rehabilitation service. Patients with diseases which may cause lower urinary tract dysfunction (polyneuropathy, benign prostatic hyperplasia, etc.) and/or using medications that may affect urodynamic results (anticholinergic, β-sympathomimetic, etc.) were excluded. Finally, a total of 83 (57 males, 26 females; median age: 32 years; range, 19 to 64 years) suprasacral traumatic SCI patients within one year after injury were included in the study. Written informed consent was obtained from each patient. The study protocol was approved by the University of Health Sciences, Ankara City Hospital, Ethics Committee (Date: 05.01.2022, No: E2-22-1227). The study was conducted in accordance with the principles of the Declaration of Helsinki.

According to the inclusion criteria and exclusion criteria, the patients were divided into two groups as complete or incomplete SCI according to the American Spinal Cord Injury International Standards for Neurological Classification of SCI.[9] Also, the patients were divided into two groups as ≤90 days or 91-365 days according to the duration between injury and urodynamics.

Urodynamic evaluation and outcome measures

We retrospectively collected records of urodynamic evaluations. Urodynamic investigations were performed using the Libra+ (MMS, Enschede, The Netherlands) urodynamic measurement system. Filling cystometry was performed with room temperature saline at a 20 mL/min filling rate. Filling ended, when the patient had a strong desire to void or discomfort and/or a leak and this volume was recorded as cystometric capacity (CC). We used urodynamic terms according of International Continence Society (ICS) definitions. The maximal storage detrusor pressure in the filling phase was accepted as Pdet (max) and Pdet (max) greater than 40 cmH_2O was recorded as Yes/No. During the filling cystometry, the presence of involuntary spontaneous and/or provocative detrusor contractions was considered as DO. Bladder compliance (BC) was calculated by dividing the bladder volume change by the change in detrusor pressure. The <20 mL/cmH_2O BC was accepted as low BC. Lack of relaxation or increased activity in sphincter electromyography during detrusor contraction was evaluated as DSD.[10]

Statistical analysis

Statistical analysis was performed using the SPSS version 15.0 software (SPSS Inc., Chicago, IL, USA). Continuous variables were presented in median (min-max), while categorical variables were presented in number and frequency. The conformity of the data to the normal distribution was examined using the Kolmogorov-Smirnov test. The Mann-Whitney U test was used for comparison of continuous variables between groups and the Pearson chi-square test was used for comparison of categorical variables between groups. A p value of <0.05 was considered statistically significant.

RESULTS

Baseline characteristics of patients are given in Table 1. The median injury duration was 115 (range, 28 to 360) days. Thirty-five (42.2%) of patients' injury durations were ≤90 days and 48 (53.8%) of patients' injury durations were 91-365 days. No statistical differences were found between the ≤90 and 91-365 days injury duration groups in age, sex, injury etiology, and severity (p>0.05). Forty (48.2%) patients had complete and 43 (51.8%) had incomplete SCI. Complete and incomplete SCI groups were similar in age, sex, injury etiology, and duration time (p>0.05).

The urodynamic parameters according to urodynamic investigation are shown in Figure 1. Fifty-two (62.7%) patients had DO, 45 (54.2%) patients had low BC, and 55 (66.3%) patients had DSD. In 35 patients who had ≤90 days injury duration, only 13 (37.1%) patients had DO, 12 (34.3%) patients had low BC, 15 (42.9%) patients had DSD, five (14.3%) had Pdet (max) >40 cmH_2O and these rates were significantly lower than the 91-365 days injury duration group (p<0.05). The median CC of 91-365 days group was lower than ≤90 days (339 [51-553], 500 [100-627], respectively; p=0.004) and the median Pdet (max) was significantly higher than ≤90 days group (43.5 [5-110], 11 [4-62], respectively; p<0.001).

Among both complete and incomplete suprasacral SCI patient groups, DO, Pdet (max) >40 cmH_2O, DSD, low BC were significantly higher in 91-365 days injury duration period group than ≤90 days period group. Also, CC was significantly lower and Pdet (max) significantly higher in 91-365 days injury duration period than at ≤90 days period (p<0.05). The DO and DSD rates of incomplete SCI patients were significantly higher than complete SCI patients within ≤90 days after injury (p=0.039 and p=0.008, respectively). Although the median Pdet (max) of incomplete SCI patients was significantly higher than complete SCI patients (p=0.007) within ≤90 days after injury, the rates of Pdet (max) >40 cmH_2O was similar between complete and incomplete SCI patients (p=0.213). Also, there were no significant differences in the median of CC and low BC rates between complete and incomplete SCI patients) within ≤90 days after injury (p>0.05). On the other hand, there were no significant differences between complete and incomplete patients in DO, BC, DSD, Pdet (max),

TABLE 1
Baseline patients' characteristics according to the duration and severity of SCI

	Interval between SCI and urodynamics							Completeness of injury							
	≤90 days (n=35)				91-365 days (n=48)			Complete (n=40)				Incomplete (n=43)					
	n	%	Median	Min-Max	n	%	Median	Min-Max	n	%	Median	Min-Max	n	%	Median	Min-Max	p^1	p^2
Age (year)			36	19-64			29	19-61			32	19-63			34	19-64	0.142	0.520
Interval between SCI and urodynamics (day)			58	28-89			167.5	94-360			129	28-360			114	29-350	<0.001	0.953
Sex																	0.989	0.175
Female	11	31.4			15	31.3			15	37.5			11	24.6				
Male	24	68.6			33	68.8			25	62.5			32	74.4				
Etiology of SCI																	0.400	0.701
Traffic accident	19	54.3			21	43.8			18	45			22	51.2				
Falling from high	11	31.4			20	41.7			17	42.5			14	32.5				
Gunshot wound	2	5.7			3	6.3			2	5			3	7				
Jumping into shallow water	3	8.6			4	8.3			3	7.5			4	9.3				
Completeness of injury																	0.700	NA
Complete (AIS A)	16	45.7			24	50			40	100			0	0				
Incomplete (AIS B-E)	19	54.3			24	50			0	0			43	100				

SCI: Spinal cord injury; AIS: American Spinal Cord Injury International Standards; p^1: Comparison of ≤90 days and 91-365 days groups; p^2: Comparison of complete and incomplete SCI groups.

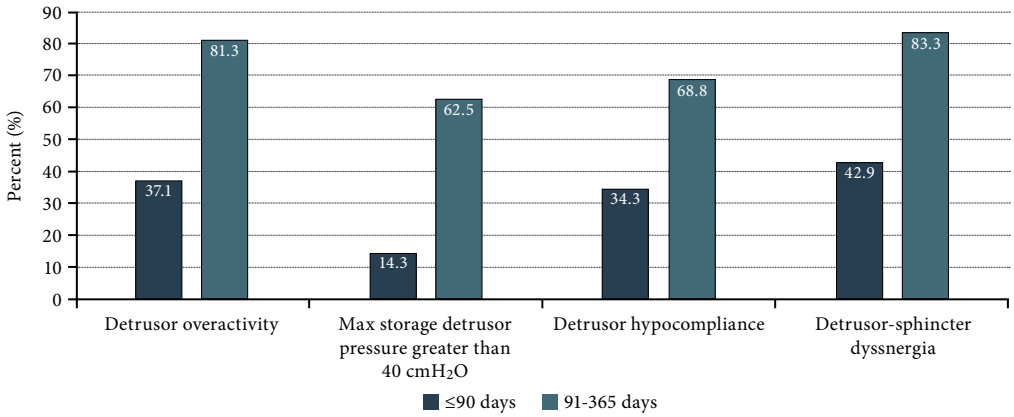

Figure 1. Comparison of urodynamic parameters in suprasacral SCI patients with <90 days and 91-365 injury duration groups.

SCI: Spinal cord injury; p^1: Comparison of detrusor overactivity <0.001; p^2: Comparison of Pdet (max) >40 cmH_2O <0.001; p^3: Comparison of detrusor hypocompliance=0.001; p^4: Comparison of detrusor-sphincter dyssynergia=0.001.

Pdet (max) >40 cmH_2O, CC within 90-365 days after injury (p>0.05) (Table 2).

DISCUSSION

In the present study, we evaluated suprasacral SCI patients within one year after the injury and investigated reflex bladder's occurrence. Thirteen patients of 35 patients with injury duration ≤90 days had DO, but Pdet (max) was higher than 40 cmH_2O in only five patients. The DO and DSD rates of incomplete SCI patients were significantly higher than complete SCI patients within 90 days after injury. Although the median Pdet (max) of incomplete SCI patients was significantly higher than that of complete SCI patients within 90 days after injury, the rates of Pdet (max) >40 cmH_2O were similar between complete and incomplete SCI patient groups. We found that the urodynamic parameters of patients with complete and incomplete suprasacral SCI were similar after three months of injury.

The principal aim of treating NLUTD in SCI patients is protecting the upper urinary tract and improving neurogenic bladder related quality of life. Therefore, in SCI patients, urodynamic guidance is necessary to identify risk factors for upper urinary tract and to manage optimal individual treatment.[8,10-12] Treatment NLUTD according to the clinical factors such as urinary incontinence or the level and severity of SCI can cause upper urinary tract complications in SCI patients.[13] The detrusor leak-point pressure and low BC have been shown to be prognostic variables for the upper urinary tract and the information about these variables can only be obtained by urodynamics. Therefore, the urodynamics is necessary for both objectively classifying and quantifying NLUTD.[14,15]

The ICS and European Association of Urology (EAU) guidelines strongly recommended performing urodynamics to manage NLUTD treatment in SCI patients; however, it is unclear when the initial urodynamics should be performed after SCI.[2,10-12] The period of spinal shock is not suitable for determining the DO by urodynamics, as detrusor is areflexic at spinal shock phase. On the other hand, the recovery of the detrusor reflex is slower than bulbocavernosus reflex or deep tendon reflex and it is often thought that the return of detrusor reflex usually takes at least four to six weeks.[16] Performing urodynamics evaluation early after injury may require repeating the urodynamics. Repeating urodynamics at short intervals would increase the risk and cost associated with the examination. On the other hand, starting of appropriate treatment as early as possible is important to avoid irreversible complications of upper urinary tract associated NLUTD. The ICS Urodynamics Committee on the SCI core panel recommend performing the initial urodynamics after the end of the spinal shock phase and then repeating urodynamics at six to 12 months after the injury.[8] On the other hand, some authors have suggested that if a patient does not develop urinary incontinence between intermittent catheterizations, urodynamics should be performed three months after injury.[2,16]

Studies about urodynamic findings in the early stage of SCI are limited and patients with sacral and suprasacral lesions were evaluated together in the most of these studies.[17-20] Rossier et al.[20] investigated 17 complete SCI patients with spinal shock (13 patients were tetraplegia and four patients were paraplegia) who underwent urodynamics one to 28 days after injury and reported that they found no vesical activity in any patients. On the contrary, Bywater et al.[19] observed a high incidence of DO within the first 40 days after SCI. They found that only 37% of 54 patients (28% of whom had complete injury) had acontractile detrusor in urodynamic findings within the first 40 days after SCI. Also, they reported that seven patients of 32 patients with DO had maximal storage detrusor pressures above 40 cmH_2O and only one patient had BC less than 20 mL/cmH_2O. Watanabe et al.[18] reported that, in 44 patients with thoracolumbar SCI within two weeks after injury, 45% of patients had detrusor areflexia, 18% had DO and 7% had DSD. In the literature, differences in the incidence of DO according to urodynamic data at the acute period after SCI may be related to heterogeneity in the severity and level of SCI of the patients included in the study.

We included only patients with suprasacral SCI our study. We found that, although all patients were out of spinal shock, 62.9% of patients still had detrusor reflexes not recover synchronously within the first three months after injury. Also, Pdet (max) were higher than 40 cmH_2O in only five (14.3%) patients. In our study, we observed that in both complete and incomplete SCI patient groups, DO, Pdet (max) >40 cmH_2O, DSD, and low BC were significantly higher in 91-365 days injury duration period than ≤90 days period. There is only one study in the literature that evaluates the neurogenic bladder of patients with suprasacral SCI in the acute-subacute period after injury. Lu et al.[5] found that at 0-30, 31-60 and 61-90 after injury, the distribution of DO in patients with complete SCI was 0%, 31.25%, 33.33% respectively, and was 9.09%, 55.56%, 87.50% in patients with incomplete SCI. In their study, DO and DSD rates were found to be significantly higher in patients with complete suprasacral SCI within >3 months injury time than patients within <3 months injury time. On the other hand, in incomplete suprasacral SCI patients while DSD was found to be significantly higher within >3 months after injury than <3 months after injury, DO was found to be similar in different periods.

TABLE 2
Comparison of urodynamic parameters between complete and incomplete suprasacral SCI patient groups

	Complete SCI								Incomplete SCI										
	Interval between SCI and urodynamics (days)								Interval between SCI and urodynamics (days)										
	≤90 (n=16)				91-365 (n=24)				≤90 (n=19)				91-365 (n=24)						
	n	%	Median	Min-Max	n	%	Median	Min-Max	n	%	Median	Min-Max	n	%	Median	Min-Max	p^1	p^2	p^3	p^4
DO (yes)	3	18.8			17	70.8			10	52.6			22	91.7			**0.039**	0.064	**0.01**	**0.004**
Pdet (max) >40 cmH_2O	1	6.3			16	66.7			4	21.1			14	58.3			0.213	0.551	**<0.001**	**0.014**
DSD (yes)	3	18.8			18	75			12	63.2			22	91.7			**0.008**	0.121	**<0.001**	**0.030**
Low BC (yes)	3	18.8			14	58.3			9	4.74			19	58.3			0.076	0.119	**0.013**	**0.030**
CC (mL)			503,5	180-530			338	123-553			461	100-627			344	51-546	0.426	0.353	**0.015**	**0.001**
Pmax det (cmH_2O)			8,5	4-62			44	5-73			30	7-60			42	19-110	**0.007**	0.812	**0.046**	**0.001**

SCI: Spinal cord injury; DO: Detrusor overactivity; Pdet (max): Maximal storage detrusor pressure; DSD: Detrusor-external sphincter dyssynergia; BC: Bladder compliance; CC: Cystometric capacity; p^1: Comparison of complete and incomplete suprasacral SCI patients at ≤90 days injury period; p^2: Comparison of complete and incomplete suprasacral SCI patients at 91-365 days injury period; p^3: Comparison of ≤90 days and 91-365 days groups in complete suprasacral SCI patients; p^4: Comparison of ≤90 days and 91-365 days groups in incomplete suprasacral SCI patients.

Although there are many studies in the literature evaluating the relationship between urodynamic parameters and completeness of SCI, most of them were conducted in the chronic period of injury. On the other hand, these studies indicate that somatic neurological findings are not always compatible with urodynamic findings.[21-23] Akkoc et al.[22] found no differences in CC and Pdet (max) urodynamic parameters between complete and incomplete suprasacral SCI patients with more than one year injury time. Also, Moslavac et al.[21] compared the CC and intravesical leak point pressure at terminal DO in complete and incomplete suprasacral SCI patients with NDO. They found no difference in leak-point pressure at CC between the complete and incomplete suprasacral SCI patients. In a retrospective study with 131 suprasacral SCI patients, urodynamic parameters of the complete and incomplete patients were compared.[23] The authors found no significant differences in DO (30.6% and 41.3%, respectively) and low BC (54.1% and 56.5%, respectively) between the complete and incomplete suprasacral SCI patients. Similar to these studies, we found that the urodynamic parameters of patients with complete and incomplete suprasacral SCI were similar after three months of injury. As opposed to this, we found that the return of reflexive detrusor function in patients with incomplete suprasacral SCI patients occurred earlier than complete suprasacral SCI patients. On the other hand, we observed that the incidence of DO and median Pdet (max) were significantly higher in incomplete patients than complete patients within three months after injury. Lu et al.[5] found that the DO rate was found to be significantly higher and CC were to be significantly lower in incomplete suprasacral SCI patients within three months after the injury period. Although it was not significant, they observed that the DO rate was higher complete suprasacral SCI patients than incomplete suprasacral SCI patients. (83.3% and 52.6%, respectively) three months after injury.

The main limitation to our study is that we were unable to compare the urodynamic data of the same patient population at different times. In the current retrospective study, we did not compare the different times after injury in the same patient population. However, due to the small sample size, we could not further group the patients according to the duration of injury. Further prospective studies with a larger sample size at the acute and subacute period after SCI would be beneficial to determine the optimal time for performing the initial urodynamics in suprasacral SCI patients.

In conclusion, although urodynamics investigation is recommended after spinal shock in SCI patients, urodynamic parameters showed that most of suprasacral SCI patients' detrusor reflex did not recover completely within three months after injury. Taken together, the development of DO in patients with incomplete suprasacral SCI occurs significantly earlier than complete suprasacral SCI patients. Urodynamics should be repeated within three to six months in patients with suprasacral SCI in whom reflex detrusor activity is not seen in the first urodynamic evaluation.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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