

# Cent European J Urol

**Citation:** Kooshesh M, Safdarian M, Nikfallah A, Vaccaro AR, Rahimimovaghar V. Association between detrusor muscle function and level of the spinal cord injury. *Cent European J Urol*. 2017; doi: 10.5173/ceju.2017.1263 [Epub ahead of print]

## Association between detrusor muscle function and level of the spinal cord injury

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[Autor's unedited version]

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**Key Words:** spinal cord injuries, urodynamic, urinary bladder

### Article history

Submitted: Feb. 14, 2017

Accepted: Dec. 26, 2017

Published online: Jan. 9, 2018

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**Introduction** Traumatic spinal cord injury (TSCI) is among the most severe disabilities with an estimation of 2.5 million people affected worldwide. The purpose of this study was to investigate the association between detrusor muscle function and level of the spinal cord injury.

**Material and methods** All patients with TSCI who underwent urodynamic evaluation in Brain and Spinal Injury Research (BASIR) Center of Imam Khomeini hospital complex from March 2014 to March 2016 were retrospectively entered this cross-sectional study. The patients were divided into three groups of suprasacral (C1-T12), sacral (L1-S5) and combined (both suprasacral and sacral) lesions.

**Results** Medical records of 117 patients with spinal cord injury were reviewed. The mean age of the patients was 35.64 ( $\pm 12.01$ ) years. 86 patients (73.5%) were male and 31 female (26.5%). 66 (56.4%), 28 (23.9%) and 19 (16.2%) patients had suprasacral, sacral, and combined suprasacral and sacral lesions, respectively. The relationship between the level of injury and emptying disorder ( $P = 0.50$ ), storage disease ( $P = 0.20$ ), first desire to void ( $P = 0.82$ ), hypocompliance ( $P = 0.95$ ), voided urine volume ( $P = 0.38$ ) and residual urine volume ( $P = 0.76$ ) were not significant. We found significant association between the level of injury and type of detrusor function ( $P = 0.019$ ).

**Conclusions** Our study showed an association between detrusor muscle function and level of the spinal cord injury. However, there was no exact relationship between the level and the completeness of the SCI with the urodynamic characteristics.

## INTRODUCTION

With an annual incidence of 130,000 new cases, traumatic spinal cord injury (TSCI) is estimated to affect 2.5 million people worldwide [1]. The global incidence of TSCI ranges from 3.6 to 195.4 patients per million [2]. The majority cases of TSCI are caused by preventable issues such as road traffic crashes, falls, and violence [3]. The damage of SCI is not just limited to the mobility of the patients but it might impose disabling complications such as spasticity, bowel and bladder dysfunction, and chronic neuropathic pain that reduce the quality of life [1].

Neurogenic bladder is one of those complications of SCI that can be life-threatening [3, 4]. More than 80% of these individuals exhibit at least some degree of bladder dysfunction and one of the most fundamental steps following the initial injury is bladder management [4]. Urologic complications continue to be an important reason for high morbidity in long-term SCI survivors [5]. Urinary disorders account for 10% of deaths in patients with complete SCI and approximately 20 times more deaths than in the general population of the same age and sex [6].

In an epidemiological study of more than one thousand Iranian patients with TSCI by Derakhshanrad et al. in 2016, urinary tract infection (UTI) followed by pressure sore (37.5%) and autonomic dysreflexia (37%) were the most common complications of these group of patients [7]. In the study by Taghipoor et al. we also found that the rate of UTI was 38.9% (1475 total patients with UTI / 3791 patients with traumatic SCI) [8].

Management of the urinary tract has an important role in improving quality of life and reducing mortality in patients with SCI. The most instructive and essential procedure for this management is the urodynamic evaluation [9]. The urodynamic investigation is the only method that can objectively assess the function of the lower urinary tract [10]. The most common urologic complications following SCI are UTI, upper and lower urinary tract deterioration, and bladder or renal stone [4]. The purpose of this study was to investigate the association between detrusor muscle function and level of the spinal cord injury.

## MATERIAL AND METHODS

### Ethics

This study was ethically approved by the Sina Trauma and Surgery Research Center, Tehran University of Medical Sciences and the ethical board approval number is 293. The information of patients remained confidential and used only for research purposes.

### Study design

All patients with TSCI who underwent urodynamic evaluation in Brain and Spinal Injury Research (BASIR) Center of Imam Khomeini hospital complex from March 2014 to March 2016 were retrospectively entered this cross-sectional study. The patients were divided into three groups of suprasacral (C1–T12), sacral (L1–S5) and combined (both suprasacral and sacral) lesions. Since there was no accurate access and discrimination to the level of spinal injury, the patients were classified according to the level of vertebral fracture. The completeness of injury was studied according to the American Spinal Injury Association (ASIA) Impairment Scale (AIS). The urodynamic data were acquired retrospectively, in addition to the demographic and SCI-related data. The method of bladder management used since the occurrence of the injury was also collected; including indwelling Foley catheter, clean intermittent catheterization, condom sheath, abdominal pressure, pad and normal micturition. Prophylactic antibiotic (a single dose of ciprofloxacin 500 mg orally) had been given to patients prior to the study; although the prophylaxis is not routinely administered in our research center it was due to the research purposes for other studies.

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## Urodynamic evaluation

Transurethral double lumen catheter was placed into the bladder with the patient in the supine position. One lumen was utilized for filling the bladder with sterile 0.9% saline in the room temperature (20°C) at the medium filling rate of 10–20 ml/min and the other lumen was used for measurement of intravesical pressure. For measurement of abdominal pressure, a rectal catheter was used. Type of detrusor function, bladder compliance, maximum cystometric capacity, external sphincter urethral function, first desire to void, voided urine volume and residual urine volume were examined.

The detrusor muscle function type was classified into overactive, underactive and normal. The bladder hypocompliance was defined as compliance <20 ml/cmH<sub>2</sub>O and normal compliance as ≥20 ml/cmH<sub>2</sub>O. The Maximum Cystometric Capacity (MCC) was considered as normal if ≥300 ml and storage disorder if less than 300 ml. Residual urine volume >50 ml in voiding phase was considered as emptying disorder. External urethral sphincter function was evaluated by sphincter electromyography to determine sphincter dyssynergia. The patients had been asked to report their first desire to void during filling phase (the first time of voiding desire that can be delayed voluntarily); the normal first desire to void was about 50% of MCC in each patient. All the urodynamic terms are according to the International Continence Society (ICS) definitions.

## Statistical analysis

Statistical analysis was performed using SPSS software version 20 (SPSS Inc., Chicago, Illinois, USA). The Chi-square test was utilized for the association between the level of injury and detrusor type, bladder hypocompliance, storage disorder, emptying disorder, external urethral sphincter function and first desire to void. The one-way ANOVA was assessed for the mean analyzing between the level of injury with the voided and residual urine volume. P values less than 0.05 were considered as statistically significant.

## RESULTS

Medical records of 117 patients with spinal cord injury were reviewed retrospectively. The mean age of the patients was 35.64 (±12.01) years (range between 13 to 74 years). 86 patients (73.5%) were male and 31 were female (26.5%). The mean interval from injury to urodynamic evaluation was 31.53 (±51.95) months. 66(56.4%), 28 (23.9%) and 19 (16.2%) patients had suprasacral, sacral and combined lesions, respectively and 4 (3.5%) patients were missing. There were 27 (23.3%) cervical, 42 (36.3%) thoracic, 24 (20.8%) lumbar and 3 (2.7%) sacral vertebral fractures, while 17 (14.9%) patients had more than one injured level. Table 1 shows the demographic and clinical findings of the patients. The association between urodynamic features and the level of injury is shown in Table 2.

There was no significant association between the level of injury and type of detrusor function (P = 0.11). Of 66 patients with the suprasacral lesion, 27 had overactive, 30 underactive and 9 patients had the normal bladder. In comparison, there were 5 overactive, 20 underactive and 3 normal bladders among the 28 patients with the Sacral lesion. Of 19 patients with combined suprasacral and sacral lesions; 4, 13 and 2 patients had overactive, underactive and normal bladders, respectively.

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Also the relationship between the level of injury and emptying disorder ( $P = 0.50$ ), storage disease ( $P = 0.20$ ), first desire to void ( $P = 0.82$ ), hypocompliance ( $P = 0.95$ ), voided urine volume ( $P = 0.38$ ) and residual urine volume ( $P = 0.76$ ) were not significant.

We recalculated all of these variables with limiting them in just two groups of suprasacral and sacral (omitting combined group) and only considering group of patients with disorder in each variable (omitting normal groups); however among all of the variables, we found significant association between the level of injury and type of detrusor function ( $P = 0.019$ ).

Our patients were further studied based on completeness of injury by AIS classification. No significant association was found between ASIA score and the level of injury ( $P = 0.64$ ).

### DISCUSSION

The aim of this study was to distinguish the differences of urodynamic features in patients with SCI with different levels of injury and to contribute to finding the appropriate clinical decision for neurogenic bladder in SCI patients. In our study, the bladder hypocompliance was found more frequent in patients with suprasacral lesions; however, Weld and Dmochowski finding was not compatible with ours, demonstrating a high frequency of impaired compliance in sacral injury group [11]. The suprasacral lesion group presented 75% of patients with overactive bladder function and the group with sacral lesion has 31.7% of patients with underactive bladder function. There were 30 patients with underactive bladder who have the suprasacral lesion, similar to other studies noted two patients of the suprasacral lesion with detrusor areflexia due to clinical or subclinical sacral cord spinal lesion [5, 12].

In our study, the rate of cervical injury was 20.7%, while other studies demonstrated higher rates of cervical injury level, as 47% by Weld et al. [11] or 50% by Agarwal et al. [5], which is possibly due to the higher rate of pre-hospital mortality in cervical cord injury in our country.

Most of the patients with complete lesions (AIS-A) in our study had the suprasacral lesion. There were 11 out of 15 (73.3%) patients with detrusor sphincter dyssynergia which had the suprasacral lesion, while 26.6% of patients did not show dyssynergia.

Although a higher value of bladder hypocompliance and detrusor sphincter dyssynergia were observed in suprasacral lesion group, we found higher voided urine volume and consequently lower residual urine volume in patients with the suprasacral lesion. The storage disorder had a higher rate (67.8%) in suprasacral lesion which had been reported previously [9], it can be consistent with more bladder hypocompliance in the suprasacral lesion. Additionally, the emptying disorder was higher (64.4%) in suprasacral lesion as well, which it may show the role of internal urethral sphincter function (innervated by hypogastric nerve originating from T10–L2).

From the aspect of bladder management method, the patients who administer catheter had more frequent in suprasacral lesion (61.7%). In the study by Schops et al. in 2015 to investigate the long-term urodynamic findings in a series of 246 patients with spinal cord injury with neurogenic lower urinary tract dysfunction, more than half of the patients relied on intermittent self-catheterization. There were significant differences between the urodynamic findings for maximum cystometric capacity, compliance and maximum detrusor pressure during storage phase at the earliest and latest available urodynamic investigations with a mean duration of 17 years while they both were within the safe limits [13].

Patients with a neurological disorder often suffer from the urinary tract, sexual, and bowel dysfunction and life-long care is usually necessary [4]. The urologic disease is still an important source of morbidity for individuals with TSCI and is more commonly compared to the general population. The incidence of serious UTIs requiring emergency room visit or hospital

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admission was reported 40% in the retrospective study of 2,023 incident TSCI patients by Welk et al. in 2016. The rate ratios for serious UTIs, urologic reconstruction/urinary diversion and renal dysfunction were significantly increased among SCI patients compared to matched controls [14]. When an efficient bladder management program is applied, the patient has less incontinence, with improved quality of life [4].

The regulation of micturition is a complex process and needs coordination between many areas in the cerebral cortex, pons and in spinal cord which involves sympathetic, parasympathetic and somatic systems [15]. Sacral micturition center at S2–S4 contains parasympathetic efferent to the bladder via the pelvic nerves, and the sympathetic efferent originates from T10–L2 level of spine via hypogastric nerves. Supra sacral spinal lesion causes detrusor overactivity and/or detrusor-sphincter dyssynergia and in contrast, injury to or below the sacral cord results in detrusor areflexia [4, 15]. Based on ICS definition, bladder compliance is described as the relationship between change in bladder volume and change in detrusor pressure and is calculated by dividing the volume change ( $\Delta V$ ) by the change in detrusor pressure ( $\Delta p_{det}$ ) during that change in bladder volume ( $C = \Delta V / \Delta p_{det}$ ), expressed in ml/cm H<sub>2</sub>O [16].

We found no exact relationship between the level of injury and the urodynamic characteristics of the SCI patients. Afsar et al. and Agarwal et al. respectively studied the relationship between the severity and the level of the injury with the urodynamic evaluation of patients with SCI in 2015 and 2016. They found no significant relationship with none of these parameters. Afsar et al. investigated the relationship between the severity of the spinal lesion and urodynamic findings, bladder drainage method at discharge, and incidence of renal calculi in 131 patients with spinal cord injury. They found no significant difference 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. They 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 [17].

In a similar study by Agarwal et al. in 2015 to evaluate the correlation between neurological level of spinal injury and bladder functions, seventy individuals with TSCI were studied through detailed clinical, neurological evaluation along with clinical examination of bladder and urodynamic study. The correlation between somatic neurologic findings, spinal imaging studies, and urodynamic findings in patients with SCI was reported not to be significant. Therefore, bladder management recommended not to completely rely on clinical bladder evaluation or neurological examination alone, but should always include urodynamic studies [5].

In another study by Yalcin and Ersoz in 2015 to investigate the bladder features and treatment options in 121 patients with lumbosacral SCI, the patients were divided into two groups of upper lumbar (L1 and L2) and lower lumbar-sacral (L3 to S5) SCIs. The rates of bladder-filling sensation, detrusor overactivity, bladder-storage and emptying disorders, prescribed emptying method, and residual urine volume were similar in both groups [9].

Perkash proposed arterial ischemia and incompleteness of injury as explanations for this inexact correlation between anatomic lesion and neurourologic clinical findings [18]. However, we also found no relationship between the completeness of the injury and the urodynamic outcomes in our study.

The current study also reports five patients of sacral who had overactive bladder, which is consistent with findings previously reported; 14.3% of individuals with sacral injuries had

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hyperreflexia and/or dyssynergia [20] and 48.9% of patients with lower lumbar-sacral SCI had detrusor overactivity [9].

We found one case with sacral fracture who had combined SCI, which may be due to root traction injury that causes spinal cord to be damaged as well and makes both suprasacral & sacral injury. Multiple injuries coexisting at different levels can result in unpredictable mixed voiding patterns. There may be of course a fair correlation between the site of lesion and subsequent neurologic dysfunction. Lesions above pontine micturition center are associated with detrusor hyperreflexia and lesions below are almost always associated with detrusor sphincter dyssynergia and autonomic dysreflexia [18].

In general, suprasacral lesions lead to detrusor overactivity and detrusor sphincter dyssynergia, whereby sacral SCI results in detrusor areflexia (and often increased bladder compliance) related to lower motor neuron lesions [17]. In a retrospective review of 316 patient records, Weld and Dmochowski tried to investigate the associations between the radiographically determined level of injury and urodynamic findings. In patients with a single level of spinal cord injury, this study revealed a significant association between the level of injury and the type of voiding dysfunction. Patients with combined suprasacral and sacral injuries, as identified with precise spinal imaging techniques, had relatively unpredictable urodynamic findings. This study also indicated that management of the urinary tract in patients with spinal cord injury must be based on urodynamic findings rather than inferences from the neurologic evaluation [11]. The aim of classifying neurogenic bladder is to facilitate better understanding of the pathophysiology behind the clinical findings, and to help in better management and changes in bladder or outlet activity may make it impossible to always predict accurately lower urinary tract activity solely on the basis of neurologic lesion [5]. The history and physical examination alone cannot determine the type of bladder and sphincter function in a person with SCI. It is imperative that complete urodynamic study is undertaken for specific identification [5].

## Limitations of the study

As a retrospective study, presence of some methodological limitations could not be avoided. However, the study can be considered to be of value in providing information about the neurogenic bladder characteristics in this group of patients.

## CONCLUSIONS

Our study findings showed that there is association between detrusor muscle function and level of the spinal cord injury. However, there is no exact relationship between the level and the completeness of the SCI with the urodynamic evaluation characteristics. Therefore, urodynamic study is recommended in all patients with SCI as it seems the bladder behavior is not predictable according to the level and completeness of the injury.

## Acknowledgments

The authors wish to thank Mrs. Maryam Ghavam for her assistance in data gathering at Urology division, Brain and Spinal Injury Research Center (BASIR), Emam Khomeini Hospital, Tehran, Iran.

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Table 1.

	Total	Suprasacral (C1–T12)	Sacral (L1–S5)	Combined SCI (Suprasacral & Sacral)
Age (years)	35.64 ±12.01	36.12 ±13.15	34.21 ±8.56	35.10 ±11.40
Gender, Male Female	86 31	44 22	25 3	15 4
Interval from injury to urodynamic study (months)	31.53 ±51.95	30.08 ±47.14	24.58 ±39.20	46.00 ±77.53
Vertebral fracture level, Cervical Thoracic Lumbar Sacral	27 58 41 4	27 39 0 0	0 0 25 3	0 19 16 1
AIS classification, A B C D	13 8 4 0	10 4 3 0	2 1 1 0	1 3 0 0
Bladder management method, F.C* CIC** Condom sheath Abdominal pressure Pad Normal	28 40 20 9 8 1	22 20 13 3 6 1	4 12 2 5 0 0	2 8 5 1 2 0

\*Foley catheter

\*\*Clean Intermittent Catheterization

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Table 2.

	Total	Suprasacral (C1-T12)	Sacral (L1-S5)	Combined SCI (Suprasacral & Sacral)	<i>p</i> value
Type of detrusor function,					0.11
Overactive	36	27	5	4	
Underactive	63	30	20	13	
Normal	14	90	3	2	
Bladder compliance,					0.95
Hypocompliance					
Normal	28	16	7	5	
	63	38	15	10	
Storage capacity,					0.20
Storage disorder	56	38	11	7	
Normal	46	22	13	11	
Emptying ability,					0.50
Emptying disorder	45	29	12	4	
Normal	11	5	5	1	
External urethral sphincter function,					0.56
Sphincter dyssynergia	15	11	1	3	
Normal	42	21	15	6	
First desire to void,					0.82
Increased	71	43	18	10	
Decreased	24	14	6	4	
Normal	17	9	4	5	
Voided urine volume (ml)	99.79 ±96.09	102.67 ±110.45	87.78 ±77.40	112.80 ±70.80	0.38
Residual urine volume (ml)	107.26 ±111.76	90.00 ±45.46	99.25 ±98.95	151.66 ±215.07	0.76

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