



Urodynamic findings in patients with complete and incomplete suprasacral spinal cord injury at different stages after injury

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Background: Urodynamics is the gold standard for evaluating the function of neurogenic bladder after spinal cord injury (SCI), but there are few studies on urodynamics in patients with complete and incomplete suprasacral SCI in different periods. There is a lack of sufficient evidence for the timing of the first urodynamic examination.

Methods: The urodynamic results of 101 patients with complete and incomplete suprasacral SCI at 0–30, 31–60, 61–90, and 91–365 days after injury were included. Urodynamic parameters were compared between 0–90 and 91–365 days, including detrusor overactivity (DO), bladder compliance (BC), bladder-filling sensation, maximum cystometric capacity (MCC), detrusor external sphincter dyssynergia (DESD), maximum urinary flow rate (Q_{\max}), detrusor pressure at a maximum urinary flow rate ($P_{\det Q_{\max}}$).

Results: There were 45 patients with complete SCI and 56 with incomplete SCI. With the course's prolongation, the proportion of DO increased gradually in patients with complete and incomplete injury within 90 days, while the MCC gradually decreased. The bladder-filling sensation of patients with complete SCI is mostly absent. Significant differences were found between 0–90 and 91–365 days in terms of DO, DESD, MCC, Q_{\max} , and $P_{\det Q_{\max}}$ in complete SCI, and DESD in incomplete SCI, and between complete and incomplete SCI in terms of DO, bladder filling sensation, MCC, Q_{\max} , $P_{\det Q_{\max}}$ at 0–90 days after injury, and bladder filling sensation at 91–365 days after injury.

Conclusions: Urodynamic examination should be conducted as soon as possible after injury in patients with incomplete suprasacral SCI, while for those with complete injury, the urodynamic examination can be initiated following clinical symptoms within 90 days after injury.

Keywords: Urinary bladder; neurogenic; spinal cord injuries (SCIs); urodynamics

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Introduction

Neurogenic lower urinary tract dysfunction (NLUTD) is a common complication after traumatic spinal cord injury (SCI) (1) and one of the common causes of death in SCI patients. Therefore, the correct evaluation and treatment of NLUTD are especially important. Urodynamics is

the only way to diagnose lower urinary tract dysfunction. The changes of bladder pressure, detrusor pressure and abdominal pressure during storage and urination were collected by a bladder pressure measuring tube and an abdominal pressure tube. Perianal surface electromyography (EMG) was used to collect the contractions of external

sphincter muscles, including urine flow rate measurement, bladder pressure-volume measurement during filling period, pressure-flow rate measurement during urination period, sphincter electromyography, urine leakage point pressure measurement, urethral pressure measurement, etc., which can objectively and quantitatively detect the status of NLUTD. It can provide the best long-term clinical efficacy, and has important guiding significance for the treatment of patients.

After suprasacral SCI, the bladder is in a shock stage for a period. With the reflex bladder recovery, most suprasacral lesions are associated with detrusor overactivity (DO) and detrusor external sphincter dyssynergia (DESD) (2,3). Long-term persistence of DO and DESD often leads to vesicoureteral reflux, ureteral dilatation, hydronephrosis, and other upper urinary tract damage that might be life-threatening. Therefore, prompt detection of DO or DESD and timely intervention treatment are crucial. However, reflex bladder recovery and the timing for performing urodynamic after SCI need to be further explored.

Previous studies have reported urodynamic in patients with a later SCI stage [3 months (3-5), over 1 year (6,7), and over 5 years after injury (8)]. However, only a few studies have investigated the urodynamic at the early stage [less than 40 days after injury (9,10)]; few urodynamic studies reported results from 40 days to 3 months after injury. Many studies have not distinguished between suprasacral and sacral SCI (8,9). However, little is known about the changes of urodynamics at different stages after suprasacral SCI.

This study aimed to analyze the changes of urodynamic parameters retrospectively in patients with complete and incomplete suprasacral SCI, examine the reflex bladder's occurrence, and the bladder function changes within one year after injury, and provide a basis for clinical treatment decision-making.

We present the following article in accordance with the STROBE reporting checklist (available at <http://dx.doi.org/10.21037/apm-21-314>).

Methods

The medical records of 215 patients with SCI at the Department of Rehabilitation Medicine of the 2nd Affiliated Hospital of Wenzhou Medical University, Wenzhou, China, were evaluated between January 1, 2016 to December 20, 2019. All procedures performed in this study involving human participants were in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of the Second Affiliated Hospital

of Wenzhou Medical University (NO.:NCT04642170). Individual consent for this retrospective analysis was waived. According to the inclusion criteria and exclusion criteria, 101 patients were included. The patients were dichotomized into the complete SCI group and the incomplete SCI group from the American Spinal Injury Association Guidelines Impairment Scale (AIS) (11). According to the interval between injury and urodynamics, patients were further divided into 0–30 days group, 31–60 days group, 61–90 days group, and 91–365 days. According to the data results, we further compared the differences of urodynamic parameters between 0–90 and 91–365 days.

Inclusion criteria are: (I) the period of the spinal shock has passed (here, spinal cord shock refers to the recovery of bulbocavernosus reflex or deep tendon reflex); (II) patients diagnosed with traumatic suprasacral SCI (the suprasacral SCI here are classified according to the results of AIS, not according to the segments of the spine); (III) the same urologist performed urodynamic investigations; (IV) patients with voiding dysfunction after SCI. The patient with voiding dysfunction before the injury was excluded.

Urodynamic evaluation

We retrospectively collected records of urodynamic evaluations. The same investigator performed a urodynamic evaluation for each patient using the Goby Urodynamic Analyzer System (Laborie[®], GBS002, Canada). Before the examination, a urinary tract infection was excluded. If anticholinergic and other drugs were used, their usage was stopped for one week. All methods, terms, and units are presented according to the standards recommended by ICS (12).

Outcome measures

The outcome measures were urodynamic parameters, including detrusor activity (stability or DO), bladder filling sensation, bladder compliance (BC), maximum cystometric capacity (MCC) and maximum urinary flow rate (Q_{max}), detrusor pressure at a maximum urinary flow rate ($P_{detQmax}$) and DESD. The BC was accepted as low compliance (<20 mL/cmH₂O), medium compliance (20–40 mL/cmH₂O) and high compliance (>40 mL/cmH₂O).

Statistical analysis

Statistical analyses were performed using IBM[®] SPSS[®] Statistics version 22. The quantitative data were

Table 1 Characteristics of patients with complete and incomplete SCI

Variable	Complete SCI (n=45)	Incomplete SCI (n=56)	P value
Age (years) (mean ± SD)	50.13±10.57	54.46±13.34	0.08
Sex, n (%)			0.12
Female	13 (28.9)	9 (16.1)	
Male	32 (71.1)	47 (83.9)	
ALS classification, n (%)			
A	45 (100.0)		
B		7 (12.5)	
C		32 (57.1)	
D		17 (30.4)	
E		0 (0)	
lesion level, n (%)			0.58
Cervical	31 (68.9)	42 (75.0)	
Thoracic	14 (31.10)	12 (21.4)	
Lumbar	0 (0)	2 (3.6)	
Interval between SCI and urodynamics (days), n (%)			0.70
0–30	8 (17.8)	11 (19.6)	
31–60	16 (35.6)	18 (32.1)	
61–90	9 (20.0)	8 (14.3)	
91–365	12 (26.7)	19 (33.9)	

SCI, spinal cord injury.

presented as mean ± standard deviations (SD), which were approximately or normally distributed. The data which was not presented as median (min–max). The categorical data were expressed as numbers and percentages. Student’s *t*-test (for quantitative data) and Chi-square test or Mann-Whitney U test (for categorical variables) are used for comparison. $P < 0.05$ was statistically significant.

Results

General information

The characteristics of patients with complete and incomplete SCI are shown in *Table 1*. No statistical differences in age, sex, lesion level, and the interval between SCI and urodynamics were found between the complete and incomplete group ($P > 0.05$).

Detrusor overactivity

As shown in *Figure 1*, at 0–30, 31–60, 61–90, and 91–365 days after injury, the proportion of DO during urine storage phase in patients with complete SCI was 0%, 31.25%, 33.33%, and 83.33%, respectively, and was 9.09%, 55.56%, 87.50%, and 52.63% in patients with incomplete SCI.

Bladder-filling sensation

Figure 2 shows the bladder-filling sensation during the patient’s storage phase with complete and incomplete SCI

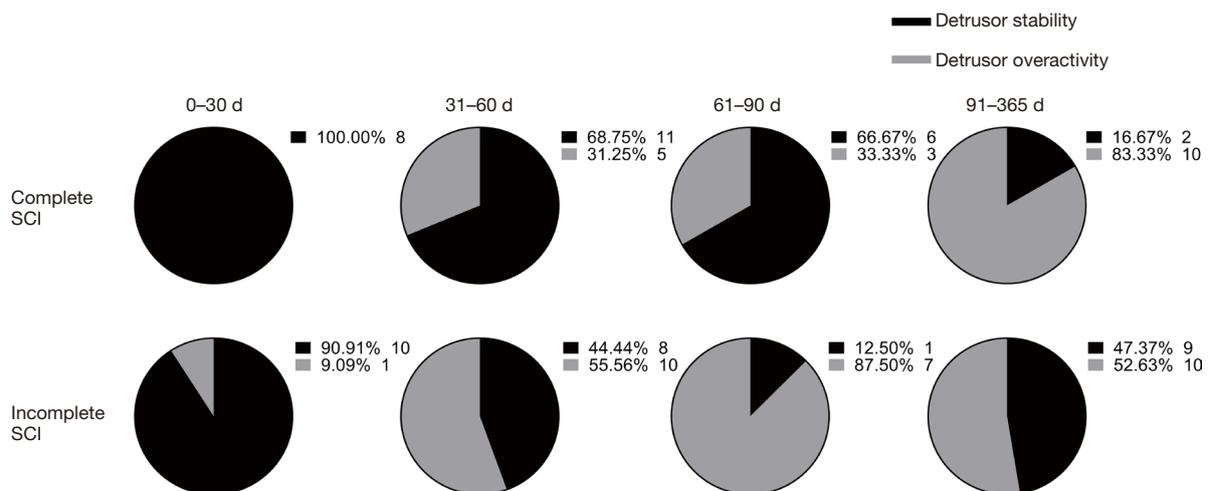


Figure 1 Detrusor activity during the storage phase of patients with complete and incomplete SCI at different stages. SCI, spinal cord injury.

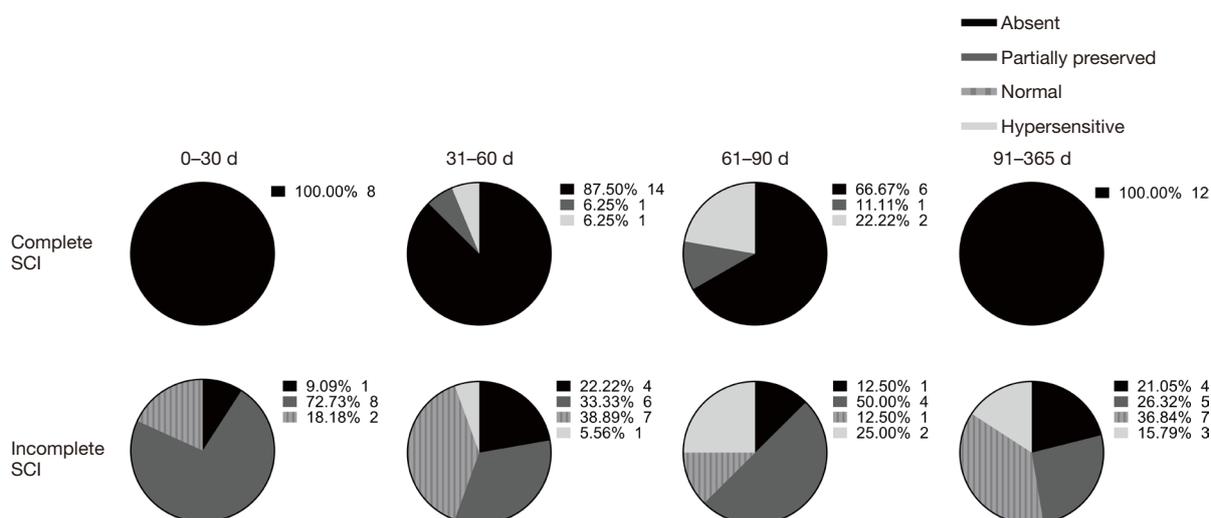


Figure 2 Sensation of bladder filling during the storage phase of patients with complete and incomplete SCI at different stages. SCI, spinal cord injury.

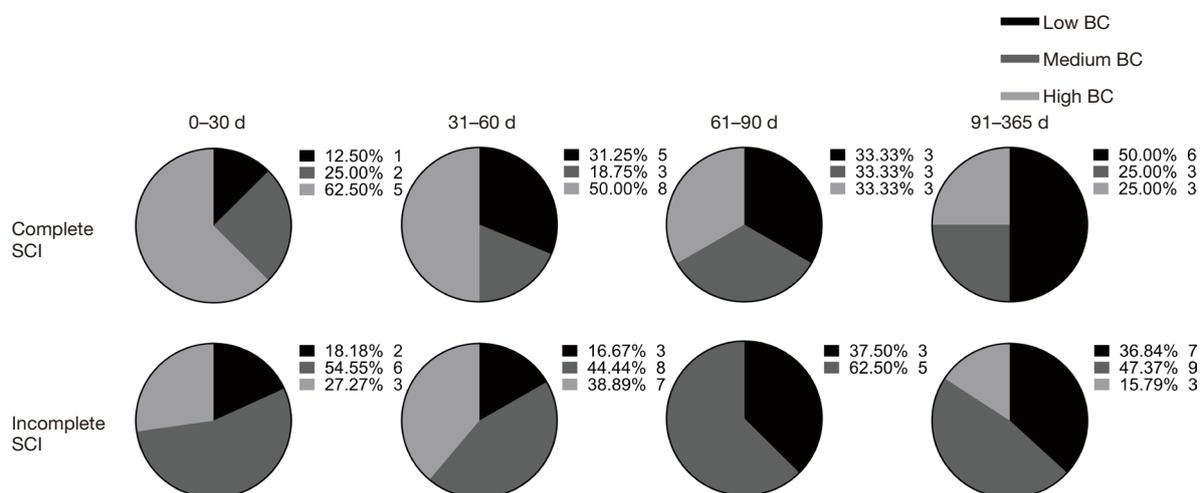


Figure 3 Bladder compliance during the storage phase of patients with complete and incomplete SCI at different stages. SCI, spinal cord injury.

at various stages. The bladder-filling sensation of patients with complete injury was mostly absent. However, in most patients with incomplete SCI was existent.

With the prolongation of the disease's course, more patients have low BC (Figure 3).

MCC, micturition capacity and detrusor contractility

As shown in Table 2, the MCC gradually decreased

with the prolongation of the course of the disease; at 0-30, 31-60, 61-90, and 91-365 days after injury, the proportion of patients with complete SCI who could urinate was 0%, 37.5%, 22.22%, and 83.33%, respectively, and was 36.34%, 44.44%, 50%, and 47.37% in patients with incomplete SCI. At 0-30, 31-60, 61-90, 91-365 days, the proportion of patients with complete SCI who have detrusor pressure was 0%, 25%, 11.11%, 83.3%, respectively, and was 18.88%, 50%, 50%, and 52.6% in

Table 2 MCC and $N_{Q_{max}}$, $N_{P_{detQ_{max}}}$ of patients with complete SCI and incomplete SCI at different stages

Course	Complete SCI (n=45)			Incomplete SCI (n=56)		
	MCC (mL) (mean \pm SD)	$N_{Q_{max}}$, n (%)	$N_{P_{detQ_{max}}}$, n (%)	MCC (mL) (mean \pm SD)	$N_{Q_{max}}$, n (%)	$N_{P_{detQ_{max}}}$, n (%)
0–30 d	717.75 \pm 32.47	0 (0)	0 (0)	560.36 \pm 119.82	4 (36.34)	2 (18.18)
31–60 d	535.69 \pm 246.77	6 (37.5)	4 (25)	421.61 \pm 196.64	8 (44.44)	9 (50.0)
61–90 d	550.00 \pm 252.53	2 (22.22)	1 (11.11)	317.50 \pm 149.97	4 (50.0)	4 (50.0)
91–365 d	335.67 \pm 224.22	10 (83.33)	10 (83.33)	358.95 \pm 201.80	9 (47.37)	10 (52.6)

$N_{Q_{max}}$, the number of patients with maximum urinary flow rate; $N_{P_{detQ_{max}}}$, the number of patients with detrusor pressure at maximum urinary flow rate; MCC, maximum cystometric capacity; SCI, spinal cord injury.

Table 3 Comparison of urodynamic parameters between complete SCI and incomplete SCI

Urodynamic parameters	Complete SCI (n=45)		Incomplete SCI (n=56)		P value			
	0–90 d (n=33)	91–365 d (n=12)	0–90 d (n=37)	91–365 d (n=19)	P1	P2	P3	P4
DO, n (%)	8 (24.2)	10 (83.3)	18 (48.6)	10 (52.6)	0.04	0.18	0.00	0.78
DESD, n (%)	6 (18.2)	8 (66.7)	7 (18.9)	12 (63.2)	0.94	1.00	0.01	0.00
Bladder filling sensation, n (%)					0.00	0.00	0.45	0.41
Absent	28 (84.8)	12 (100.0)	6 (16.2)	4 (21.1)				
Partially preserved	2 (6.1)	0 (0)	18 (48.6)	5 (26.3)				
Normal	0 (0)	0 (0)	10 (27)	7 (36.8)				
Hypersensitive	3 (9.1)	0 (0)	3 (8.1)	3 (15.8)				
Bladder compliance, n (%)					0.21	0.79	0.12	0.24
Low BC	9 (27.3)	6 (50.0)	8 (21.6)	7 (36.8)				
Medium BC	8 (24.2)	3 (25.0)	19 (51.4)	9 (47.4)				
High BC	16 (48.5)	3 (25.0)	10 (27)	3 (15.8)				
$P_{detQ_{max}}$	0 (0–84)	36 (0–84)	0 (0–43)	0 (0–57)	0.02	0.12	0.00	0.22
MCC (mean \pm SD)	583.73 \pm 225.13	335.67 \pm 224.22	440.35 \pm 185.88	358.95 \pm 201.81	0.01	0.77	0.00	0.14
Q_{max}	0 (0–9)	5.5 (0–15)	0 (0–18)	0 (0–18)	0.04	0.06	0.00	0.96

P1, comparison of urodynamic parameters between complete SCI and incomplete SCI at 0–90 days after injury; P2, comparison of urodynamic parameters between complete SCI and incomplete SCI at 91–365 days after injury; P3, comparison of urodynamic parameters in patients with complete SCI between 0–90 and 91–365 days; P4, comparison of urodynamic parameters in patients with incomplete SCI between 0–90 and 91–365 days. SCI, spinal cord injury; DO, detrusor overactivity; DESD, detrusor external sphincter dyssynergia; BC, bladder compliance; $P_{detQ_{max}}$, detrusor pressure at maximum urinary flow rate; MCC, maximum cystometric capacity; Q_{max} , maximum urinary flow rate.

patients with incomplete SCI.

Comparison of urodynamic parameters between complete and incomplete injury in 0–90 and 91–365 days

The comparison results of urodynamic parameters between complete and incomplete injury at 0–90 and 91–365 days

are shown in *Table 3*. Significant differences were found in DO, bladder-filling sensation, $P_{detQ_{max}}$, MCC, Q_{max} between complete and incomplete SCI at 0–90 days, and only bladder-filling sensation at 91–365 days (all $P < 0.05$). The DO, DESD, $P_{detQ_{max}}$, MCC, Q_{max} in the complete SCI, and DESD in incomplete SCI are significantly different between 0–90 and 91–365 days ($P < 0.05$).

Discussion

Main findings

We found most of the patients with complete suprasacral SCI were in the bladder shock stage at 0–90 days, showing loss of bladder filling sensation, no detrusor contraction, no DO, and DESD, no micturition, and large bladder capacity, especially at 0–30 days. At 91–365 days, most patients had DO, but some patients were still in the shock stage. Bladder filling sensation was absent in all patients with complete SCI. However, different results were found in patients with incomplete SCI. The return of reflexive detrusor function in patients with incomplete SCI occurred earlier than in those with complete SCI. Also, some patients with incomplete SCI have DO at 0–30 days.

Findings in the context of existing evidence

Most clinicians estimate the reflexive bladder function's return usually takes at least 4 to 6 weeks (13). Ditunno *et al.* summarized the spinal cord's neurophysiology and neuroplasticity after SCI and concluded that the reflex bladder recovery occurs one month after injury (14). The correct judgment of the recovery of bladder function depends on the urodynamic examination. So far, only a few studies have reported urodynamic results in the early stage of SCI. Bellucci *et al.* (9) compared the urodynamic parameters in ambulatory *vs.* non-ambulatory patients with acute SCIs (duration since SCI was from 14 to 39), but they did not distinguish between suprasacral and subsacral SCI. Watanabe *et al.* (15) studied the urodynamic results in patients with SCI after thoracolumbar fracture (AIS C–E) with a course of 3–14 days before spinal surgery, suggesting that some patients had lower urinary tract dysfunction.

Many clinical studies reported urodynamic results on SCI with a long disease course over 1 year (6–8,16,17). Some studies disregarded the course of the disease (18); other studies did not distinguish between suprasacral and subsacral injuries (8,9), or between complete and incomplete injuries (2,5,6,8,19). A retrospective study (20) compared urodynamics between suprasacral complete and incomplete SCI in 131 patients. The results showed that DO accounted for 30.6% of complete SCI, 41.3% were with incomplete SCI; low BC accounted for 54.1% of complete SCI, 56.5% of incomplete SCI, and bladder feeling absent accounted for 76.5% of complete SCI. However, this study was conducted over an extended period, and it included patients with traumatic SCI and non-traumatic patients. Agrawal *et al.* (4)

studied the urodynamics in patients with traumatic SCI over three months and found that in 65 patients with suprasacral injury, 53 (81.5%) demonstrated hyperreflexia, 6 (9.2%) detrusor areflexia, and 6 (9.2%) had normal bladders, 41 (59.4%) low compliance. Still, the results of this study do not distinguish between complete and incomplete SCI. So far, only a few studies have addressed urodynamics changes with the course of disease after SCI; few studies reported on urodynamics within 90 days after SCI. Therefore, there is no sufficient basis for determining the recovery time of the reflex bladder after injury.

Implications for practice

Although the importance of urodynamic investigations in patients with NLUTD is undisputed, there is no unified conclusion on when the first urodynamic examination should be performed after SCI and the interval of follow-up. Some studies suggested that urodynamic examination should be performed after the recovery of bladder function following acute SCI, three months after injury (13). The members of the International Continence Society (ICS) Urodynamics Committee on the SCI core panel recommend performing the first exam as soon as possible after the end of the spinal shock phase and then conducting repeated testing at 6 and 12 months after the injury (21).

In this study, we found that the reflexive bladder in most patients with complete suprasacral SCI did not recover at 0–90 days, which was not the case for incomplete SCI. Thus, for our data, the urodynamic examination should be performed as early as possible in patients with incomplete injury, while for those with complete injury, the examination can be started following clinical symptoms within 90 days after injury. It is recommended to re-do testing after 3 months.

Implications for research

The definition of spinal shock and the pattern of reflex recovery or evolution is still debatable. Also, the identification of clinical signs that determine the duration of spinal shock is controversial (22). In classical teaching, the termination of spinal cord shock refers to the recovery of bulbocavernosus reflex or deep tendon reflex, which usually lasts for several days or weeks, with an average duration of 4–12 weeks. The recovery of the detrusor reflex is slower compared to bulbocavernosus reflex or deep tendon reflex (14). All the patients selected in this study had bulbocavernosus reflex or/and deep tendon reflex, while the

detrusor reflex did not recover synchronously in patients with complete SCI. Most patients did not recover until three months after injury, or even longer. The cause of the delayed recovery of the bladder reflex is unknown and needs to be further studied. It is also necessary to further examine the potential relevance of recovery of reflex detrusor activity as spinal cord shock termination.

The bladder's sensory information is transmitted through A- δ fibers; it ascends in the spinal cord via the spinothalamic and spinobulbar tracts and finally reaches the cerebral cortex (23). Therefore, when the spinal cord is injured, the bladder sensation's afferent is theoretically blocked and cannot be transmitted to the cerebral cortex. Therefore, the bladder sensation in patients with complete SCI is usually absent. However, like some studies, this study's results also showed there are still a few patients with bladder sensation; the reason for this phenomenon is not clear and needs further investigation.

Study limitations

In the present retrospective study, we did not compare the different times after injury in the same patient. However, this study still has a strong guiding significance for clinical practice.

Conclusions

The urodynamic results are different at various stages after injury. The urodynamic findings of patients with complete suprasacral SCI differed significantly from patients with incomplete suprasacral SCI within 90 days after injury. Urodynamic parameters showed that most patients' reflex bladder function did not recover completely from injury within 90 days after injury. Our data suggest that urodynamic examination should be conducted as soon as possible after injury in patients with incomplete suprasacral SCI. However, a urodynamic examination can be initiated for those with complete injury following clinical symptoms within 90 days after injury. All patients with complete and incomplete injuries must undergo urodynamic examination again after 3 months.

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Footnote

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