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ARTICLE

Combining different evaluations of sensation to assess the afferent innervation of the lower urinary tract after SCI

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Abstract

Study design Retrospective cohort study.

Objectives To study a combination of three evaluations of sensation in the lower urinary tract (LUT) in patients with spinal cord injury (SCI).

Setting University Antwerp Belgium, Unicenter study.

Methods Evaluation of perineal sensation with light digital touch, reporting of filling sensation during a standardised urodynamic investigation and determination of the electrical perception threshold (EPT) were evaluated in patients with SCI.

Results 150 individuals were included: 97 men and 53 women, mean age 46 ± 17 years. Patients had different levels and completeness of SCI, and different techniques for bladder emptying. Seventy-four patients (49%) reported sensation to touch in the perineal area. Sensation of bladder filling was reported in different patterns by 81 patients (54%). EPT was determined in 69 patients of which 50 (72%) reported sensation in different patterns. The outcome of absence/presence of sensation between the three tests differed greatly: with perineal sensation absent 53% had filling sensation ($p = 0.040$) and 58% positive EPT ($p = 0.009$). With filling sensation absent 59% had EPT sensation (not significant). Perineal sensation was strongly associated with level and completeness of SCI, while a significant association existed for filling sensations FSF, FDV, SDV and EPT in the distal urethra.

Conclusions Our study shows that different evaluations of sensation in the LUT of individuals with SCI complement each other. and we therefore propose combined use in the urological evaluation of patients with SCI to allow a more complete picture of the LUT sensations.

Introduction

The lower urinary tract (LUT) has an extensive peripheral innervation to transport afferent information from its different parts to the spinal cord and brain. In normal life proper sensation of what happens in the bladder is the prerequisite for voluntary control of a mainly autonomic innervated organ system. When a spinal cord lesion occurs, disruption of this intricate nervous network will cause dysfunction in ±90% of patients [1]. LUT dysfunction is amongst the most dangerous hazards in spinal cord injury (SCI) with a strong negative impact on quality of life, related to the urological symptoms and the method of bladder emptying [2]. Information on the sensory function of the LUT is therefore important in the assessment and diagnosis of LUT dysfunction. Different techniques have been described. In order to evaluate this further and define what each evaluation adds to the sensory diagnosis we performed three different investigations of the LUT sensation in patients with SCI in a single session as an integral part of the urological examination. The contribution of each and the differences between tests were analysed.

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Methods

A retrospective cohort study was conducted after approval of the local ethical committee. As per standard practice, the urological examination of patients with SCI in our centre consists of an extensive history taking on the signs and symptoms related to the LUT, current or past treatments, and possible complications/red flags such as fever, haematuria, pain, inflammation in the pelvic region and autonomic dysreflexia (AD) [3]. If UTI was present, AD difficult to control or one of the other conditions listed above existed, patients were excluded ($n = 21$). The study population included no patients with neuromodulation, or a history of bladder augmentation. Six patients had received botulinum toxin A injection (five intradetrusor and one intrasphincteric) prior to our investigation (months before). Many patients used antimuscarinics at the time of the evaluation. These were not excluded to allow a real-life picture in this population. Literature on the effect of such drug intake on sensation in patients with neurogenic bladder is scarce [4]. The single session setting of our study did not allow to evaluate such drug effect specifically.

Three techniques were used to assess LUT sensation. These techniques are an integral part of our standardised urological evaluation of patients with SCI.

The subjective reporting of presence of sensation to light digital touch in the different dermatomes of the perineal area S2–S5 was evaluated with the patient blinded to the procedure. The assessment includes a test of the patient's compliance and reliability by asking for sensation without touching [5].

Patients were requested to report all sensations while cystometric bladder filling was done through a transurethral catheter (8 Fr) at a continuous flowrate of 30 ml/min with radiocontrast solution at room temperature [6]. Statham pressure transducers, and five channel urodynamic software (Medical Measurement Systems, Gladbeck, Germany) were used. When no or little pressure developed, filling was stopped at 550 ml (the capacity of the filling solution bottle). Filling was also stopped when neurogenic detrusor overactivity occurred with leakage, when the detrusor pressure rose constantly above 40 cm H_2O, or when a strong desire to void (SDV) was reported. The normal pattern of sensation of bladder filling has been well described before [7, 8]. Normal sensations of bladder filling during cystometry are first sensation of filling (FSF), first desire to void (FDV), strong desire to void (SDV). These sensations were evaluated in relation to the bladder volume and in relation to the patient's symptomatic complaints. In pathological situations (e.g. SCI), different patterns of sensation can be found: absence of sensation, only one or two different sensations of bladder filling, or abnormal sensations such as pain. Non-specific bladder awareness is defined as perception of bladder filling as abdominal fullness, vegetative symptoms, spasticity or other "non-bladder awareness [7, 8].

Electrical perception thresholds (EPT) were determined by providing a bipolar continuous electrical current with square wave impulses at frequency of 2.5 Hz (pulse width 1 ms, pause 400 ms) and with gradual increasing amplitude till a sensation was reported or until a max current of 80 mA was reached. The bipolar current was provided through two ring electrodes mounted 1 cm apart on a transurethral catheter. The electrodes were radiographically positioned, respectively, against the bladder wall, in the posterior urethra and in the distal urethra. The bladder was not prefilled. Stimulation through surface electrodes on a normally innervated skin area ruled out a generalised sensory deficiency. Absence of electrical sensation was accepted when an amplitude of 80 mA was reached and no sensation was reported. Different patterns of sensation were found: normal sensation, absence of sensation or diminished sensation. An increased EPT was defined as more than 11 mA in the bladder, 6 mA in the posterior urethra immediately under the bladder neck, and 6 mA in the distal uretha (distal 3–4 cm of the penile urethra and distal 1 cm of the female urethra). In some patients one part of the LUT could not be evaluated because of difficulties to introduce the catheter or correctly position the electrodes. Two or three EPT determinations were consecutively done per location, and the data were considered reliable if differences were not above 0.29 mA for bladder wall, 0.21 mA for posterior urethra and 0.13 mA for distal urethra. This was previously demonstrated to have a 95% chance that the mean value is between mean and reliability border (Wyndaele PhD Thesis UA 1993, p. 179).

After the tests all patients received antibacterial prophylaxis with Fosfomycine 3 g. Exact Fisher test was used for comparison of absence/presence of sensation between the tests. Statistical significance was set at $p < 0.05$.

Results

150 patients had both an evaluation of perineal sensation and of sensation of bladder filling, 97 males and 53 females, mean age 46 ± 17years (17–79 years). The tests were performed 8 ± 13 years after SCI as part of regular follow up ($n = 96$) or as part of indicated evaluation ($n = 54$), e.g. for changed spasticity, increase in AD. Evaluation of EPT was performed in 69 patients (equipment was not available for the entire study period).

SCI aetiology was mostly traumatic (Table 1). Level and completeness of SCI and the method of bladder emptying are presented in Table 1.

Table 2 provides the results of the three different sensation evaluations.

Seventy-four patients (49%) reported sensation of touch in the perineal area. Sensation of bladder filling was reported in different patterns by 81 patients (54%). EPT was determined in 69 patients of which 50 (72%) reported sensation in different patterns. Table 3 presents the comparison of the outcome of the different tests. The absence/presence of sensation between the three tests differed greatly: with perineal sensation absent 53% had filling

Table 1 Aetiology, level and completeness of SCI and method of bladder emptying.

Cause of SCI		
Road traffic accident	64	
Fall	32	
Sport	12	
Myelitis	9	
Vascular	5	
Surgery	13	
Myelopathy	3	
Tumour	7	
Work accident	4	
Gun shot	1	
Total	150	
Level and completeness of SCI		
	Complete (AIS A)	Incomplete (AIS B–D)
C1–C8	23	38
T1–T9	31	14
T10–L1	11	15
L2–S3	3	8
Conus/cauda	3	4
Total	71	79
Method of bladder emptying		
Clean intermittent catheterisation	61	
Transurethral indwelling catheter	46	
Normal voiding	13	
Suprapubic catheter	8	
Tapping	2	
Crédé/straining	19	
Total incontinence	1	
Total	150	

SCI spinal cord injury.

Table 2 Outcomes of perineal sensation, sensation of bladder filling and EPT.

	N	%		Total
Sensation to perineal touch (S3–S5)				
Absent	69	46		
Present bilateral	78	52		
Unilateral	3	2		150
Sensation of bladder filling during cystometry				
Absent	76	51		
Reports 1 sensation	23	15		
Reports 2 consecutive sensations	18	12		
Reports 3 consecutive sensations (normal)	22	15		
Reports different sensations	11	7		150
EPT				
No sensation in all parts of the LUT	19	28		
Has normal sensation	9	13		
Increased all locations	3	4		
Different between locations	31	45		
Not possible in all locations	7	10		
Pathologic where done			3	
Normal where done			4	69

EPT electrical perception threshold.

Table 3 Comparison of the outcome of the different tests.

	N	%	*N*	%	Total
Sensation to perineal touch (S3–S5)					
	Absent		Present		
Sensation of bladder filling during cystometry					
Absent	48	32	21	14	
Present	28	19	53	35	150
EPT					
Absent	14	20	12	17	
Present	5	7	38	55	69
EPT	Absent		Present		
Sensation of bladder filling during cystometry					
Absent	13	19	10	14	
Present	6	9	40	58	69

EPT electrical perception threshold.

sensation ($p = 0.040$) and 58% positive EPT ($p = 0.009$). With no filling sensation reported 59% had EPT sensation (not significant). Perineal sensation was strongly associated with level and completeness of SCI (0.001), while a significant association existed for filling sensations FSF ($p = 0.035$), FDV ($p = 0.041$), SDV ($p = 0.046$) and EPT distal urethra ($p = 0.004$). Absence/presence of EPT of the bladder wall related significantly with absence/presence of SDV, EPT of the posterior urethra with FSF and FDV, EPT of the distal urethra with FDV and perineal sensation.

Discussion

This is to our knowledge the first study to describe the single session test outcome of three different methods to evaluate LUT sensation in SCI patients. Previously published results of the different tests have shown differences in prevalence of sensory pathology in patients with SCI, illustrating that SCI can cause vastly different neurological deficits [9, 10]. In our study, we found a large increase in presence of sensation related to the LUT when all three tests were combined. Our data also showed a statistically good association between level and completeness of SCI (AIS Impairment scale) and the sensation of light touch of the perineum, while the correlations with filling sensation and electrosensation were significant for all filling sensations and EPT of the distal urethra.

The neuro-anatomy of the LUT is very complex and specific. Afferent nerve fibres from the LUT peripherally run in the hypogastric (T10–L2), the pelvic (S2–S4) and the pudendal nerves S2–S4 [11]. The afferents of the different dermatomes of the perineal skin run through the pudendal nerves, whereas the sensation of bladder filling runs in all three types of peripheral nerves. There has been some suggestion in previous clinical studies (small case series of patients having undergone sacrum resection) that the different sensations of bladder filling each mainly run through a different afferent pathway: FSF through the hypogastric, FDV through the pelvic and SDV through the pudendal plexus [12, 13]. Finally, sensation elicited by electrical stimulation runs through the peripheral nerves that innervate the area being stimulated: lateral bladder wall through the pelvic, posterior urethra through the hypogastric and distal urethra through the pudendal plexus. The afferent nerves mostly run through the spinal ganglion and posterior roots on their way to the spinal cord [14]. In the spinal cord, the contralateral spinothalamic tract carries exteroceptive potentials (from electrical stimulation) after they cross at 1–2 spinal nerve segments above the point of entry. Sensations of bladder filling ascend in the ipsilateral posterior columns as does sensation of perineal touch. The three tests of LUT sensation therefore cover partly different pathways from peripheral to the central nervous system, each consisting of peripheral and spinal cord components. Depending on the level and completeness of the SCI, different parts of each pathway may be disrupted or lesioned. It was previously shown that neuromodulation on S3 influences the nervous system involved in electrosensation of the bladder wall but not the afferent innervation of the skin or the nerves involved in urethral electrosensation [15]. The data show that S3 neuromodulation is effective mainly through the pelvic afferent nerves. It may therefore be important to test these specific nerves in patient selection for sacral neuromodulation in SCI. Ersoz and Akyuz found a clinical value in sensation-dependent bladder emptying after SCI [9], but not all patients with incomplete SCI were willing to use it [16].

Furthermore, it has also become clear that the classification into AIS complete (A) or incomplete (B–D) does not fully correspond with absence or presence of visceral sensation below the level. Finnerup et al. [17] evaluated sensation evoked by painful or repetitive stimulation below injury level in patients with a clinically complete (AIS A) lesion. Their findings suggest retained sensory communication across the injury in complete SCI, and they suggested the term ‘sensory discomplete’. Similar findings have been made for sensation of bladder filling and electrosensation in the LUT [18]. It has been described that the International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI) do not provide information about the status of a person’s remaining autonomic function [19].

The tests we used were easy to perform and have reproducible results [18]. The poor association between the tests was also previously reported. The absence of somatic sensation of the perineal skin was poorly associated with sensation of bladder filling. Volume and pressure at different sensations of bladder filling did not associate with EPT values [18]. These previous findings could also be explained by our hypothesis that these tests examine different (peripheral or central) parts of the sensory innervation of the LUT. This diagnostic challenge needs further investigation.

There are several studies that evaluated the diagnostic value of sensory information from the LUT. Alexander et al. [20] described that a greater ability to perceive pinprick and light touch in the T6–T9, T11–L2 and S3–S5 dermatomes also increased the likelihood to perceive bladder filling. We could not confirm that last association in our study. Schurch et al. [21] found that the AIS sensory scores did not allow prediction of bladder function after SCI at level T12–L1. Preservation of perineal pinprick sensation had no positive predictive value, though absence of pinprick sensation from start predicted poor bladder recovery. Pavese et al. included light-touch sensation in the S3 dermatome in their interesting system to predict outcomes of the bladder [22]. Sayılır et al. [23] detected significantly more patients with C1–C5 lesions with preserved sensation of bladder filling than in the group with a C6–C8 lesion, which they explained by the higher incomplete injury rate in the upper cervical lesions. We found more incomplete lesions in the C2–C8 group taken together, and a correlation with filling sensations and the level/completeness of SCI. Ersöz and Sayılır [24] investigated the possible preventive effect of sensation of bladder filling on upper urinary tract deterioration in SCI patients at least 3 years after trauma. Deterioration was lowest if normal sensation of bladder filling was present,which was the case in <10% of their study population, but also indicate unchanged bladder function. In those with partially preserved or absent sensation of filling, upper tract problems were found in around 40%. Reitz [25] compared presence or absence of sensation of bladder filling in a small cohort with complete spinal cord conus or cauda equina lesions and neurologically unimpaired patients. He found that 29% with complete lesion of conus, and 91% with complete cauda equina lesion reported a filling sensation, which the author explained by sensory transfer through an intact hypogastric plexus. Our small number with this type of lesion (conus/cauda), does not permit us to investigate this. Intravesical electrostimulation (IVES) could induce recovery of FSF in a high percentage of incomplete SCI suffering from chronic neurogenic non-obstructive retention who responded to IVES [26]. One can hypothesise that the repeated stimulation may recreate awareness. Lombardi et al. compared the efficacy of IVES versus sacral neuromodulation in patients with incomplete spinal cord lesions and neurogenic non-obstructive urinary retention. Following the two procedures, the FSF was either maintained or recovered by all responders [27].

It has been stated in international guidelines that more attention should be given to sensation [28]. Our study showed that after SCI, the resulting neuropathy is vastly different between patients, and that preservation of (parts of the) sensory pathways is frequent. Furthermore, absence/presence of one LUT sensation does not imply the absence/presence of the others. We therefore suggest combined assessment of the different pathways in patients with SCI through evaluation of perineal sensation, sensation of bladder filling and determination of EPT. This approach may provide a more complete picture of which sensory pathways are working, which sensations are present and how they can be of value in the management. However, determining a possible diagnostic and therapeutic value needs further study.

Data availability

The data such as curves of urodynamics testing are in the patient files. Data from the database are available on request to the corresponding author, blinded for patient name and file number and other information that might consist a breach of confidentiality.

Author contributions JJW collected the file data, put them in a database, made evaluations and wrote the text. MW commented on the study design, made evaluations, and corrected the text where needed.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval We certify that all applicable institutional and governmental regulations concerning the ethical use of the data were followed during this research.

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