ORIGINAL ARTICLE

Neuropathic bladder dysfunction in patients with motor complete and sensory incomplete spinal cord lesion

C-A Rapidi, K Petropoulou, A Galata, M Fragkaki, E Kandylakis, M Venieri and Ch Tzavara

2nd Department of Physical and Rehabilitation Medicine, Neuropathic Bladder Unit, National Rehabilitation Center, EIAA, Athens, Greece

Study design: A retrospective study of patients with motor complete spinal cord lesion and somatosensory preservation (American Spinal Injury Association (ASIA) impairment scale B).

Objective: To determine whether neuropathic bladder dysfunction is more or less severe with more or fewer complications in patients with somatosensory preservation.

Setting: 2nd Department of Physical and Rehabilitation Medicine, Neuropathic Bladder Unit, National Rehabilitation Center, EIAA, Athens, Greece.

Methods: The classification of spinal cord injured patients was determined according to ASIA protocol. All patients underwent urodynamics and retrograde cystography, with a follow-up period of at least 18 months. The study sample consisted of 154 patients: 28 ASIA B patients compared with 126 ASIA A patients. We analyzed 140 traumatic and 14 nontraumatic lesions for (1) specific type of neuropathic bladder, (2) detrusor overactivity volume and pressure, (3) bladder compliance, (4) vesicoureteric reflux, (5) formation of bladder stones, (6) method of bladder emptying and (7) daily dose of anticholinergics needed to achieve safe bladder function. We also studied the presence of spasticity, autonomic dysreflexia and pain syndrome.

Results: Statistically significant differences were found between ASIA A and B patients in daily dose of anticholinergics needed to achieve safe bladder function, in the incidence of incontinence episodes and in formation of bladder stones.

Conclusion: Patients with somatosensory incomplete lesion of spinal cord seem to have an advantage in the management of neuropathic bladder dysfunction (fewer anticholinergics needed, fewer incontinence episodes and fewer bladder stones).

Spinal Cord (2008) 46, 673–678; doi:10.1038/sc.2008.16; published online 4 March 2008

Keywords: spinal cord injury; incomplete spinal cord lesion; neuropathic bladder dysfunction; neurogenic bladder; vesicoureteric reflux; bladder stones

Introduction

Following a spinal cord lesion (SCL), patients present neuropathic bladder dysfunction that can influence not only the upper urinary tract function, but the quality of life as well.¹ Risk factors for deterioration of the upper urinary tract have been already described and concern patients with low bladder compliance and high detrusor pressures (Pdets) during the storage and emptying phase.^{2–5}

According to international standards for neurological classification of SCL of the American Spinal Injury Association

(ASIA), completeness or incompleteness of a lesion is defined clinically by the presence or absence of motor and/or sensory function through all neurotomes down to the sacral ones.⁶ The ASIA impairment scale does not take into account the status of function of the autonomic nervous system (ANS) for practical reasons. ANS cannot be easily assessed clinically except by certain cardiovascular reflexes.^{7,8} The ANS innervating lower urinary tract can be assessed by urodynamics and sophisticated electrophysiological tests;^{9,10} both are carried out during subacute phases post SCL. The ASIA impairment scale has the great advantage that it can be applied from the first moments postlesion, but it is a clinically evaluated scale that is relevant only to the somatic nervous system. The aim of this retrospective study was to assess the influence of partial somatosensory preservation down to the sacral neurotomes in lower urinary tract dysfunction (ANS dysfunction).

Correspondence: Dr C-A Rapidi, 2nd Department of Physical and Rehabilitation Medicine, Neuropathic Bladder Unit, National Rehabilitation Center, EIAA, 26 Alkiviadou street, Drafi, Mailing Box 606, 19009 Attiki, Greece.
E-mail: rapidicha@hotmail.com

Received 16 August 2007; revised 21 January 2008; accepted 30 January 2008; published online 4 March 2008

Methods

Subjects

The determination of neurological level and completeness/incompleteness of lesion was made according to ASIA protocol and the ASIA impairment scale.⁶ Out of 780 patients with SCL who were evaluated over the course of 10 years in the Neuropathic Bladder Unit of our department, we retrospectively studied patients with the following inclusion criteria: motor and sensory complete lesion (ASIA A) or motor complete and sensory (light touch or/and pinprick) incomplete lesion (ASIA B), no progressive lesion of spinal cord, chronic lesion (12 or more months post lesion) and long-term follow-up with the last evaluation of at least 30 months post lesion.

Patients with more than one level of injury, cauda equina lesions, multiple sclerosis or with no data concerning the cause of SCL were excluded. Patients were grouped into the following four subgroups according to the neurological level of lesion: subgroup (1) lesions C4 to T1, ASIA A or B (A1 and B1 groups, respectively); subgroup (2) lesions T2–6, ASIA A or B (A2 and B2 groups); subgroup (3) lesions T7–9, ASIA A or B (A3 and B3 groups) and subgroup (4) lesions T10–12, ASIA A or B (A4 and B4 groups).

All patients had undergone urodynamics and kidney and bladder ultrasound annually post lesion and retrograde cystography biannually post lesion, based on an established follow-up protocol. Exceptionally, if patients presented any change in neurolurologic condition, they also underwent the tests. According to our protocol, any medication that could alter detrusor and urethral sphincter function was discontinued at least 1 week before the first urodynamic tests. Urodynamics during follow-up were done with no medication discontinuation in order to assess the therapeutic results. All patients were evaluated for urinary tract infection (UTI) before urodynamics. If significant bacteriuria and leucocyturia were present, urodynamics were postponed and patients were first treated.

Methods, definitions and units conformed to the standards recommended by International Continence Society (ICS), except where specifically noted. In this study, the first and last follow-up tests were considered.

The specific type of neuropathic bladder dysfunction was defined according to ICS terminology¹¹ and Mandersbacher's classification.¹² Detrusor and sphincter overactivity or underactivity and detrusor–external sphincter dyssynergia (DESD) were confirmed by urodynamics and anal sphincter electromyography. Although anal sphincter electromyography is not always concomitant with urethral electromyography, the method was chosen for practical reasons. The anal surface electrode has easier application and better stabilization and compliance during urodynamics compared to a concentric needle electrode for urethral sphincter. The DESD was defined as continuous (cDESD) when increased electromyography (EMG) activity appeared simultaneously with detrusor overactivity without incontinence. The DESD was defined as intermittent (iDESD) when increased EMG activity with a fluctuating character appeared simulta-

Table 1 Patient's distribution according to the neurological level of lesion

	ASIA A (N = 126) N (%)	ASIA B (N = 28) N (%)
<i>Subgroup</i>		
1: C4–T1	A1: 33 (26.2)	B1: 20 (71.4)
2: T2–6	A2: 32 (25.4)	B2: 2 (7.1)
3: T7–9	A3: 29 (23.0)	B3: 2 (7.1)
4: T10–12	A4: 32 (25.4)	B4: 4 (14.3)

Abbreviation: ASIA, American Spinal Injury Association.

neously with detrusor overactivity and was followed by episodes of incontinence.

We also studied the following: bladder compliance (considered low: $<20 \text{ ml cm}^{-1} \text{ H}_2\text{O}$), overactivity volume (bladder volume at first occurrence of detrusor overactivity) and detrusor pressure at that volume, vesicoureteric reflux, autonomic dysreflexia (documented either during urodynamics or by episodes needing medical intervention), spasticity and pain syndrome (documented by medication needed), stone formation in the bladder documented by plain X-rays or ultrasounds, method of bladder emptying and daily dose of anticholinergics needed to achieve 'safe' intravesical pressure during storage and emptying phase ('safe' intravesical pressure $<40 \text{ cm H}_2\text{O}$). The incidence of incontinence episodes was studied in patients under intermittent catheterizations and Valsalva or Crede maneuvers. The incidence of symptomatic UTIs needing treatment was studied during the last year of follow-up according to patients' reports.

Demographics

The sample consisted of 154 subjects, 126 in ASIA A group and 28 in ASIA B group. Table 1 shows the number of patients in ASIA A and B according to the neurological level of lesion. A total of 118 men (mean age, 34.6 years; s.d., 13.7 years) and 36 women (mean age, 38.3 years; s.d., 14.9 years) were analyzed. The mean time post lesion was 26.7 years (s.d., 18.9 years). The etiology of lesion was traumatic in 140 patients and nontraumatic in 14 patients (ASIA A: four patients with vascular/ischemic lesions, four patients with neoplastic etiology, one patient with cervical spondylosis; ASIA B: three patients with vascular/ischemic lesions, two patients with cervical spondylosis). The mean follow-up was 5.8 years.

Statistical analysis

Continuous data are presented with means (s.d.) while qualitative data are presented with absolute and relative frequencies. The unpaired Student's *t*-test was used to evaluate any possible differences in means between the two groups (ASIA A and B). For comparisons of proportions, χ^2 and Fisher's exact tests were used. Subgroup comparisons between ASIA A and B patients were conducted only for A1 and B1 subgroups because of the small number of patients in ASIA B (2–4) subgroups (Table 1). All *P*-values reported are two-tailed. Statistical significance was set at 0.05 and analysis was conducted using STATA 7.0 (STATA, College Station, TX, USA).

Table 2 Patient's characteristics presented by ASIA A and ASIA B groups

	ASIA A (N = 126) N (%)	ASIA B (N = 28) N (%)	P
<i>First assessment</i>			
Sex			
Men	95 (75.4)	23 (82.1)	0.446 ^a
Women	31 (24.6)	5 (17.9)	
Age, mean (s.d.)	34.1 (12.6)	41.6 (18.3)	0.048 ^b
Spasticity	70 (55.6)	17 (60.7)	0.618 ^a
Dysreflexia	20 (15.9)	6 (21.4)	0.576 ^c
Pain syndrome	9 (7.1)	2 (7.1)	1.000 ^c
Pdet at reflex volume without anticholinergics, mean (s.d.)	66.6 (19.3)	58.9 (15.0)	0.050 ^b
Reflex volume, mean (s.d.)	210.6 (118.8)	217.7 (114.4)	0.797 ^b
Type of neuropathic bladder			
Overactive detrusor+iDESD	30 (23.8)	9 (32.1)	0.649 ^a
Overactive detrusor+cDESD	87 (69.0)	17 (60.7)	
Underactive/acontractile	9 (7.1)	2 (7.1)	
Compliance			
Normal	117 (92.9)	25 (89.3)	0.458 ^c
Decreased (<20 ml cm ⁻¹ H ₂ O)	9 (7.1)	3 (10.7)	
<i>Follow-up (last assessment)</i>			
Method of bladder emptying			
Reflex voiding	9 (7.1)	3 (10.7)	0.288 ^c
Intermittent catheterization	107 (84.9)	21 (75.0)	
Indwelling catheter	7 (5.6)	4 (14.3)	
Valsalva/Credé manœuvres	3 (2.4)	0 (.0)	
Daily dose of anticholinergics			
No	19 (15.1)	6 (21.4)	0.009 ^a
10–15 mg oxybutinine	74 (58.7)	22 (78.6)	
20–30 mg oxybutinine SR	33 (26.2)	0 (0.0)	
Vesicoureteric reflux			
No	116 (92.1)	27 (96.4)	0.690 ^c
Yes	10 (7.9)	1 (3.6)	
Bladder stones			
No	102 (81.0)	27 (96.4)	0.048 ^c
Yes	24 (19.0)	1 (3.6)	
UTI			
<2 per year	107 (84.9)	25 (89.3)	0.767 ^c
≥2 per year	19 (15.1)	3 (10.7)	
Episodes of incontinence			
No incontinence	27 (24.5)	10 (47.6)	0.009 ^c
1–3 episodes per month	20 (18.2)	5 (23.8)	
1–6 episodes per week	33 (30)	6 (28.6)	
One or more episodes per day	30 (27.3)	0 (0)	

Abbreviations: ASIA, American Spinal Injury Association; cDESD, continuous detrusor-external sphincter dyssynergia; iDESD, intermittent detrusor-external sphincter dyssynergia; Pdet, detrusor pressure; SR, slow releasing; UTI, urinary tract infection.

^aχ²-test.

^bStudent's *t*-test.

^cFisher's exact test.

Results

The values of study variables for ASIA A and B groups are presented in Table 2. No gender differences were found between the two groups. The mean age for patients in ASIA B group was 41.6 years (s.d., 18.3 years) and was higher than those of age of ASIA A group of 34.1 years (s.d., 12.6 years).

First assessment

Patients presented three types of bladder dysfunction: (1) overactive detrusor with cDESD, (2) overactive detrusor with iDESD and incontinence during urodynamic study and (3) underactive/acontractile detrusor with sphincter over-activity. All patients with ASIA B realized (subjective report) passage of the urethral catheter during urodynamics, in

contrast to all ASIA A patients. There were no clear data for the first desire to void in the majority of our patients; in some cases there was only an abnormal sensation of bladder filling or a sensation concomitant with detrusor reflex contraction, usually combined with autonomic dysreflexia in patients with lesion above T6. For these reasons, we did not proceed with further analysis of these data.

Patients with ASIA B presented lower Pdet at overactivity volume ($P=0.05$). Poor bladder compliance was present in 12 patients (7.8%), with no significant difference between ASIA A and B groups. No significant differences were found between the two groups regarding overactivity volume, type of neuropathic bladder, spasticity, dysreflexia or pain syndrome.

Follow-up (last assessment)

No significant differences were found between the two groups regarding the method of bladder emptying; the vast majority of the patients were under intermittent catheterization (84.9% of ASIA A group and 75% of ASIA B group). The 10–15 mg daily dose of oxybutinine in order to achieve 'safe' intravesical pressure during the storage and emptying phase was more frequent in ASIA B group, while more patients in ASIA A group needed a high daily dose of anticholinergics (20–30 mg of oxybutinine SR; $P=0.009$), and 17 out of 107 patients under high dose of anticholinergics in ASIA A group did not achieve safe bladder filling and emptying. The proportion of patients with bladder stones was greater in ASIA A group than those in ASIA B group (19.0 vs 3.6%, $P=0.048$). No significant differences were found between the two groups in occurrence of vesicoureteric reflux or of UTI. Table 3 presents comparisons of study variables between patients with tetraplegia (ASIA A1 and B1 subgroups). More subjects had bladder stones in ASIA A1 subgroup than those in ASIA B1 subgroup (30.3 vs 5.0%, $P=0.037$). Furthermore, greater daily doses of anticholinergics were more frequent in ASIA A1 subgroup (33.3%) than that in ASIA B1 subgroup (0%). The distribution of the number of episodes of incontinence was different when compared between ASIA A and B groups and between ASIA A1 and B1 subgroups. More patients were found to have one or more episodes per day in ASIA A compared with ASIA B group (25.4 vs 0%) and in ASIA A1 compared with ASIA B1 (33.3 vs 0%) subgroup. Consistent with this finding, the proportion of patients without incontinence was greater in ASIA B group and ASIA B1 subgroup in comparison with the corresponding ASIA A group and ASIA A1 subgroup.

Discussion

Patients with SCL, either traumatic or nontraumatic, present neuropathic bladder dysfunction of mainly four types: detrusor and sphincter mechanism overactivity, detrusor and sphincter mechanism underactivity, detrusor underactivity and sphincter mechanism overactivity, and detrusor overactivity and sphincter mechanism underactivity.¹³ Patients in this study presented mainly detrusor and sphincter overactivity; only a few presented acontractile detrusor with sphincter overactivity. This is probably the

result of exclusion of lesions caudally to T12 neurotome. The decision for excluding patients with SCL caudally to T12 neurotome was made in order to study only SCLs and avoid mixed lesions of upper and lower motor neurons or cauda equina lesions. Only patients in chronic phase (at least 1 year post injury) were included in this study in order to ensure a stable neurological status of ASIA B group. The specific types of neuropathic bladder dysfunction, as above, did not differ significantly between ASIA A and B or ASIA A1 and B1 patients, although detrusor hyperactivity had a more benign character in ASIA B and B1 patients, and lower daily doses of anticholinergics were needed. The correlation between the detrusor sphincter dyssynergia type and incompleteness or completeness of SCL has been studied.^{14,15} In the present study, the different types of dyssynergia (cDESD, iDESD) did not differ between groups ASIA A and B; this could be explained by the fact that both groups were patients with complete motor lesion. Continuous DESD was present in the majority of our patients (104 out of 154 patients) and in 69.0% of ASIA A patients and 60.7% of ASIA B patients, but this difference did not reach statistical significance. The same pattern was present in subgroups A1 and B1. This finding is in agreement with Weld *et al.*,¹⁵ who found continuous spasms of the external sphincter usually in SCI patients with complete lesions.

The proportion of patients with bladder stone formation was greater in ASIA A group than those in ASIA B group. Although it is well known that bladder management with indwelling catheter is associated with a substantial increased risk of bladder stone formation,¹⁶ in the present study bladder management with indwelling catheter was more frequent in ASIA B patients, who were mainly tetraplegics, than that in ASIA A patients (14.3 and 5.6%, respectively). Despite this, patients with ASIA B presented less frequent stone formation compared with ASIA A patients (3.6 and 19.0%, respectively). In our series, bladder stone formation was diagnosed by ultrasound or plain X-rays.

Although it is well documented that somatosensory deficits are not always paralleled with viscerosensory loss and vice versa,^{17–19} the lower Pdet at overactivity volume and the lower daily dose of anticholinergics needed in ASIA B patients indicates a more benign type of detrusor hyperreflexia in patients with somatosensory preserved function. Schurch *et al.*²⁰ studied 55 post-traumatic paraplegic patients with a spinal fracture at the thoracolumbar level and found that preservation of perineal pinprick sensation was of no positive predictive value but of negative predictive value: absence of pinprick sensation predicted poor bladder recovery. The interpretation given by the authors referred to the proximity of ANS tracts to the most dorsolateral fibers in the spinothalamic tract. Therefore, preservation of perineal pinprick sensation indicates at least some sparing of the adjacent ANS fibers and ultimately indicates a more benign type of bladder dysfunction. Additionally, partial somatosensory preservation of sacral neurotomes could interfere with detrusor overactivity, as the guarding reflex is driven by afferent input, affecting motor pathways through synaptic activity with interneurons either at a local segmental level or via axons to the brain.²¹

Table 3 Comparison of patient's characteristics between ASIA A1 and ASIA B1 subgroups

	ASIA A1 (N = 33) N (%)	ASIA B1 (N = 20) N (%)	P
<i>First assessment</i>			
Sex			
Men	25 (75.8)	17 (85.0)	0.503
Women	8 (24.2)	3 (15.0)	
Age, mean (s.d.)	31.4 (11.2)	38.9 (17.7)	0.101 ^a
Spasticity	24 (72.7)	14 (70.0)	0.831 ^a
Dysreflexia	13 (39.4)	6 (30.0)	0.489 ^a
Pain syndrome	1 (3.0)	2 (10.0)	0.549 ^b
Pdet at reflex volume without anticholinergics, mean (s.d.)	67.6 (19.6)	61.8 (15.7)	0.267 ^a
Reflex volume, mean (s.d.)	226 (144.5)	230.6 (109.3)	0.797 ^a
Type of neuropathic bladder			
Overactive detrusor+iDESD	9 (27.3)	8 (40.0)	0.607
Overactive detrusor+cDESD	21 (63.6)	11 (55.0)	
Underactive/acontractile	3 (9.1)	1 (5.0)	
Compliance			
Normal	32 (97.0)	18 (90.0)	0.549
Decreased (<20 ml cm ⁻¹ H2O)	1 (3.0)	2 (10.0)	
<i>Follow-up (last assessment)</i>			
Method of bladder emptying			
Reflex voiding	4 (12.1)	2 (10.0)	0.569
Intermittent catheterization	26 (78.8)	14 (70.0)	
Indwelling catheter	3 (9.1)	4 (20.0)	
Valsalva/Credé manœuvres	—	—	
Daily dose of anticholinergics			
No	6 (18.2)	3 (15.0)	0.005
10–15 mg oxybutinine	16 (48.5)	17 (85.0)	
20–30 mg oxybutinine SR	11 (33.3)	0 (0.0)	
Vesicoureteric reflux			
No	28 (84.8)	19 (95.0)	0.390
Yes	5 (15.2)	1 (5.0)	
Bladder stones			
No	23 (69.7)	19 (95.0)	0.037
Yes	10 (30.3)	1 (5.0)	
UTI			
<2 per year	30 (90.9)	18 (90)	1.000 ^b
≥2 per year	3 (9.1)	2 (10)	
Episodes of incontinence			
No incontinence	7 (26.9)	7 (50)	0.050 ^b
1–3 episodes per month	3 (11.5)	3 (21.4)	
1–6 episodes per week	7 (26.9)	4 (28.6)	
One or more episodes per day	9 (34.6)	0 (0)	

Abbreviations: ASIA, American Spinal Injury Association; cDESD, continuous detrusor-external sphincter dyssynergia; iDESD, intermittent detrusor-external sphincter dyssynergia; Pdet, detrusor pressure; SR, slow releasing; UTI, urinary tract infection.

^aStudent's *t*-test.

^bFisher's exact test.

Conclusions

In conclusion, it would be wise for patients with SCL to be classified with more data and electrophysiological tests as to the completeness or incompleteness of the somatic nervous system and the ANS as well. Somatosensory incomplete lesion of spinal cord seems to interfere with detrusor overactivity. A lower daily dose of anticholinergics needed

for safe bladder filling and emptying, and lower incidence of urine incontinence and bladder stone formation are advantages in patients with ASIA B lesion.

References

- 1 Ku JH. The management of neurogenic bladder quality of life in spinal cord injury. *BJU Int* 2006; **98**: 739–745.

- 2 McGuire EJ, Woodside JR, Borden TA, Weiss RM. Prognostic value of urodynamic testing in myelodysplastic patients. *J Urol* 1981; **126**: 205–209.
- 3 Yokoyama O, Hasegawa T, Ishiura Y, Ohkawa M, Sugiyama Y, Izumida S. Morphological and functional factors predicting bladder deterioration after spinal cord injury. *J Urol* 1996; **155**: 271–274.
- 4 Van Kerrebroeck PE, Koldewijn EL, Scherpenhuizen S, Debruyne FM. The morbidity due to lower urinary tract function in spinal cord injury patients. *Paraplegia* 1993; **31**: 320–329.
- 5 Ku JH, Choi WJ, Lee KY, Jung TY, Lee JK, Park WH *et al*. Complications of the upper urinary tract in patients with spinal cord injury: a long-term follow-up study. *Urol Res* 2005; **33**: 435–439.
- 6 Maynard Jr FM, Bracken MB, Creasey G, Ditunno Jr JF, Donovan WH, Ducker TB *et al*. International Standards for Neurological and Functional Classification of Spinal Cord Injury. American Spinal Injury Association. *Spinal Cord* 1997; **35**: 266–274.
- 7 Hilz MJ, Dutsch M. Quantitative studies of autonomic function. *Muscle Nerve* 2006; **33**: 6–20.
- 8 Nagarajao HS, Kumar BN, Watt JW, Wiredu E, Bhamidimarri K. Bedside assessment of sympathetic skin response after spinal cord injury: a brief report comparing inspiratory gasp and visual stimulus. *Spinal Cord* 2006; **44**: 217–221.
- 9 Craggs MD. Pelvic somato-visceral reflexes after spinal cord injury: measures of functional loss and partial preservation. *Prog Brain Res* 2006; **152**: 205–219.
- 10 Schmid DM, Curt A, Hauri D, Schurch B. Clinical value of combined electrophysiological and urodynamic recordings to assess sexual disorders in spinal cord injured men. *Neurol Urodyn* 2003; **22**: 314–321.
- 11 Abrams P, Cardozo L, Fall M, Griffiths D, Rosier P, Ulmsten U *et al*. The Standardisation of Terminology of Lower Urinary Tract Function: Report from the Standardisation Sub-committee of the International Continence Society. *Neurol Urodyn* 2002; **21**: 167–178.
- 12 Madersbacher H. The various types of neurogenic bladder dysfunction: an update of current therapeutic concepts. *Paraplegia* 1990; **28**: 217–229.
- 13 Wyndaele JJ, Madersbacher H, Kovindha A. Conservative treatment of the neuropathic bladder in spinal cord injured patients. *Spinal Cord* 2001; **39**: 294–300.
- 14 Schurch B, Schmid DM, Karsenty G, Reitz A. Can neurologic examination predict type of detrusor sphincter-dyssynergia in patients with spinal cord injury? *Urology* 2005; **65**: 243–246.
- 15 Weld KJ, Graney MJ, Dmochowski RR. Clinical significance of detrusor sphincter dyssynergia type in patients with post-traumatic spinal cord injury. *Urology* 2000; **56**: 565–568.
- 16 Ord J, Lunn D, Reynard J. Bladder management and risk of bladder stone formation in spinal cord injured patients. *J Urol* 2003; **170**: 1734–1737.
- 17 Wyndaele JJ. Investigation of the afferent nerves of the lower urinary tract in patients with ‘complete’ and ‘incomplete’ spinal cord injury. *Paraplegia* 1991; **29**: 489–494.
- 18 Schmid DM, Reitz A, Curt A, Hauri D, Schurch B. Urethral evoked sympathetic skin responses and viscerosensory evoked potentials as diagnostic tools to evaluate urogenital autonomic afferent innervation in spinal cord injured patients. *J Urol* 2004; **171**: 1156–1160.
- 19 Curt A, Rodic B, Schurch B, Dietz V. Recovery of bladder function in patients with acute spinal cord injury: significance of ASIA scores and somatosensory evoked potentials. *Spinal Cord* 1997; **35**: 368–373.
- 20 Schurch B, Schmid DM, Kaegi K. Value of sensory examination in predicting bladder function in patients with T12-L1 fractures and spinal cord injury. *Arch Phys Med Rehabil* 2003; **84**: 83–89.
- 21 Fowler CJ. Integrated control of lower urinary tract—clinical perspective. *Br J Pharmacol* 2006; **147** (S2): 14–24.