



Dartos reflex as autonomic assessment in persons with spinal cord injury

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Abstract

Study design Prospective clinical series.

Objectives The dartos reflex (DR) produces unilateral elevation of the testis with vermicular contraction of the scrotal skin and penile retraction. It is a somato-autonomic reflex that depends on the T11-L2 sympathetic segment. Its presence was analysed in men with various levels and severities of spinal cord injury (SCI).

Setting France.

Methods Male patients with SCI undergoing urodynamic or sexual assessment were included. DR of the scrotum and penis were systematically assessed in addition to the usual neurological examination that included assessment of the autonomic system, cremaster, and sacral reflexes. The DR was evoked by applying a small ice pack on the scrotum, separately to each side.

Results Forty-six patients were assessed. DRs were always present when the T11-L2 segment was intact above the lesion (low paraplegia below L2) or below the lesion in an upper motor neuron (UMN) syndrome (spastic paraplegia above T10). They were more pronounced in the case of UMN syndrome. In the case of lower motor neuron (LMN) syndrome that included the T11-L2 segment, DRs disappeared in all but one patient. Patients with a LMN lesion were more prone to retrograde or absent ejaculation, loss of psychogenic erection, and open bladder neck.

Conclusions The DR is a valuable test for the assessment of the integrity and excitability of the T11-L2 spinal segment. It is easy to perform and is predictive of some aspects of sexual and bladder neck function in men. DR should be considered as an addition to the autonomic standards.

Introduction

Spinal cord injury (SCI) disrupts the descending spinal voluntary motor and involuntary autonomic pathways, resulting in dysfunctions of the cardiovascular and broncho-

pulmonary systems, sudomotor, urinary bladder, bowel, and sexual organs [1, 2]. Specific spinal centres have been identified as important for the control of the urinary bladder, bowel, and sexual organs (Fig. 1). The sacral S2–S4 segments contain the parasympathetic (pelvic nerve) and the somatic (pudendal nerve) centres, and the T11-L2 segment contains the sympathetic centre (hypogastric nerves). The T11-L2 sympathetic centre is responsible for psychogenic sexual arousal (psychogenic erection) and semen emission, as well as bladder neck control (closing during ejaculation and opening during micturition) [3].

Assessment of the integrity (or not) of this centre is thus of paramount importance in persons with SCI, particularly if the patient has sexual and/or urinary symptoms. The neurological classification of SCI (ISNCSCI) provides some information regarding function, but is mainly limited to sensory testing of the T10 to L2 dermatomes, with one key

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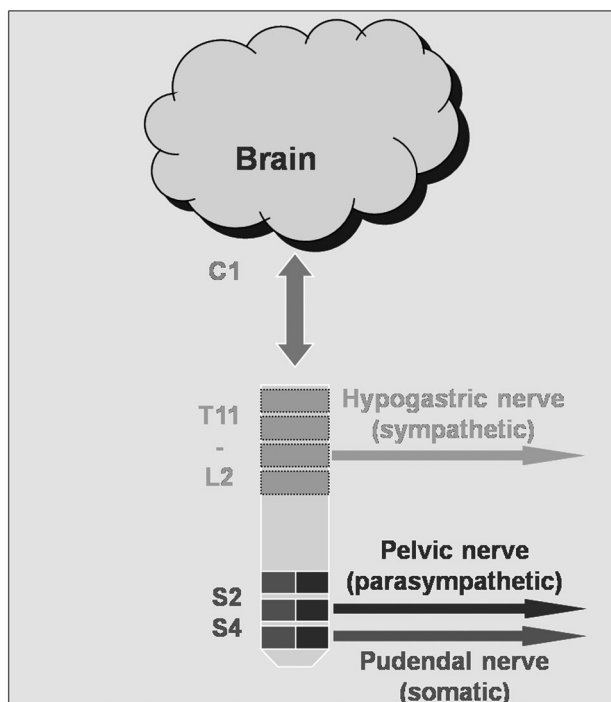


Fig. 1 Schematic representation of the autonomic and somatic nervous system

motor test involving the psoas muscle (L2) [4]. Complementary neurological somatic and autonomic assessments are thus required [5].

Scrotal reflexes depend on the integrity of the T11-L2 segment, and consist of elevation of the testis and retraction of the penis. Spontaneous migration of the testis between the scrotum and the inguinal canal in response to cold, arousal, and coitus is common in men. Although it may be embarrassing, this response is physiological and is easy to assess [6–8].

There are two distinct scrotal reflexes, the cremasteric (CR) and the dartos (DR) reflexes [6, 9, 10]. The cremaster muscle is a striated muscle that originates from the internal oblique muscle and descends along the spermatic cord. The DR muscle is a smooth muscle found in the dermal layer of the scrotum. Contraction of these muscles in response to cold results in constriction of the dermal vessels, decreases the surface area for heat loss, and pulls the testicles toward the abdomen, minimizing heat loss. The DR muscle is also incorporated in the penile skin and responsible for penile retraction [9].

The DR and cremaster muscles are innervated by the genitofemoral nerve that arises from the T12 and L2 spinal roots and provides sensory innervation to the upper thigh, scrotum, and scrotal contents, motor somatic innervation to the cremaster muscle (genital nerve) and autonomic innervation to the DR muscle [9, 11].



Fig. 2 a and b: Dartos reflex in a patient with complete T6 AIS A paraplegia. After cold stimulation (2b), there is an incomplete elevation of the testes, and nearly complete penis retraction

The CR is evoked by cutaneous stimulation of the medial thigh and produces a quick elevation of the ipsilateral testis, while the DR is evoked ipsilaterally by local cold on the scrotum, and produces a slow, writhing, vermicular contraction of the scrotal skin together with testis elevation [6, 9, 11]. While both reflexes have been demonstrated by electromyography, [10, 12] DR has not been assessed in men with SCI.

The aim of this series was to evaluate the utility of the DR for the evaluation of the integrity of the T11-L2 spinal segments. We hypothesized that the DR would be a useful addition to the autonomic standards [1, 2], and that it would relate to the level and completeness of the SCI, and to hyperactivity of the spinal cord below the lesion.

Methods

Patients

From January 2017, the DR was included in the routine clinical neurological examination of male patients in our department. The ISNCSCI was also routinely evaluated, including sacral and autonomic reflexes, to determine the presence of an upper (UMN) or a lower motor neuron (LMN) syndrome in the spinal cord below the lesion. Autonomic tests include pilomotor (piloerection or goose bumps) and sudomotor (sweating) reflexes on the legs (T10-L2 innervation) and trunk, in response to stimulations above the lesion (encephalic reflexes) or below the lesion (spinal reflexes) usually with pressor stimuli such as bladder filling or penile vibratory stimulation (PVS) [13, 14]. The sympathetic vasomotor responses (skin axon-reflex vasodilatation) is evaluated by mechanically stimulating the skin (using a blunt instrument, such as the edge of a wooden tongue depressor) on both sides of the trunk, inducing a spreading flush (vasodilation or dermatographia rubra) on normally innervated skin [5, 14].

Patients with SCI who were addressed for either urodynamic, bladder, or sexual assessments were assessed with the DR in the study.

Procedure

The DR was evoked by applying a small ice pack on the scrotum, separately to each side (Fig. 2a, b). The DR of the scrotum was rated as absent, or present; when present, the elevation of the testis could be incomplete (testis remains in

the scrotum) or complete (full migration of the testis into the inguinal canal). Similarly, the DR of the penis was rated as absent or present; when present, the penis retraction could be incomplete (partial retraction) or complete (penis completely hidden below the surface of the skin). The DRs were also evaluated during PVS or bladder filling, depending which tests the patients underwent.

Reflex erection, ejaculation and orgasm were assessed during PVS trials in our clinical setting, while psychogenic erections were reported by patients.

Urodynamic tests, including detrusor, urethral and rectal pressure recordings were carried out in most patients. Cystometry (50 ml min^{-1}) was carried out in the supine position with saline at room temperature using a Geyre

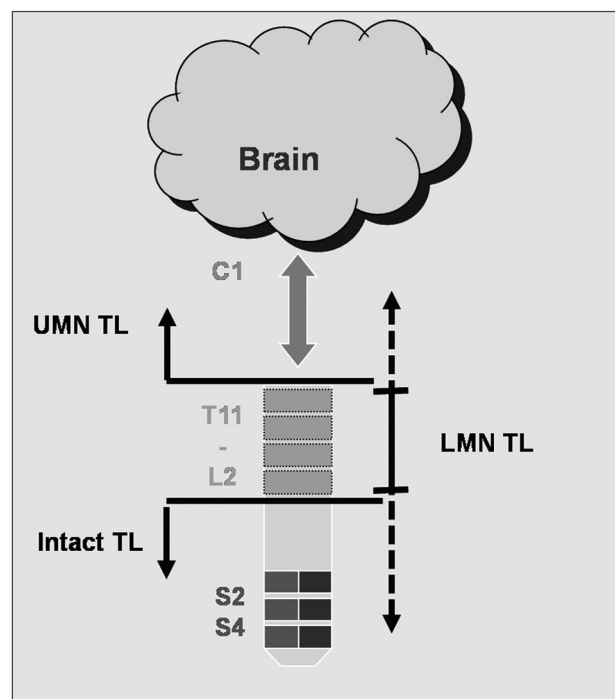


Fig. 3 Schematic representation of the groups according to the level of lesion and integrity of the T11-L2 segment. *UMN* upper motor neuron, *LMN* lower motor neuron, *TL* thoraco-lumbar

Table 1 Patient characteristics

	<i>n</i>	Level	Severity		Below the lesion	
			Complete (AIS A-B)	Incomplete (AIS C-D)	UMN	LMN
UMN TL	21	9/12	19	2	21	–
Intact TL	9	–/9	6	3	9	–
LMN TL	16	–/16	16	–	10	6
<i>Above T10</i>	7	–/7	7	–	1	6
<i>At T11-L2</i>	9	–/9	9	–	9	–

UMN upper motor neuron, *LMN* lower motor neuron, *TL* thoraco-lumbar

Table 2 Somatic and autonomic results for each patient

SCI	Age	Evol	Level	AIS	Group	Dartos		Autonomic reflexes		Erection		Ejaculation	Orgasm	Bladder		Neck
						Scrotum	Penis	Cremaster	Encephalic	Spinal	Psychogenic			Reflex	Contraction	
1	Tetra	38	16,8	C4	C	UMN TL	+	+	-	+	+	-	-	+	BND	
2	Tetra	36	3,7	C4	A	UMN TL	+	+	0	0	-	na	+	+	Normal	
3	Tetra	46	16,6	C5	A	UMN TL	+	+	T03	+	0	0	0	+	Normal	
4	Tetra	37	20,2	C6	A	UMN TL	+	+	T03	+	0	+	+	+	BND	
5	Tetra	50	22,5	C6	A	UMN TL	+	+	T03	+	0	na	+	+	BND	
6	Tetra	41	21,1	C6	C	UMN TL	+	+	T03	+	+	+	+	+	BND	
7	Tetra	69	8,0	C6	A	UMN TL	+	+	T03	+	0	na	+	+	BND	
8	Tetra	26	2,8	C6	B	UMN TL	+	+	T09	+	0	na	+	+	Normal	
9	Tetra	20	2,3	C6	A	UMN TL	+	+	T03	+	0	-	+	+	BND	
10	Para	31	14,3	T02	A	UMN TL	+	+	-	+	+	+	+	+	Normal	
11	Para	34	10,0	T02	A	UMN TL	+	+	T03	+	0	0	+	+	BND	
12	Para	52	39,2	T02	A	UMN TL	+	+	T04	+	0	+	+	+	BND	
13	Para	60	27,3	T03	A	UMN TL	+	+	T04	+	0	na	+	+	BND	
14	Para	45	21,3	T04	A	UMN TL	+	+	T08	+	0	na	+	+	-	
15	Para	55	4,2	T05	A	UMN TL	+	+	T05	+	0	+	+	+	Normal	
16	Para	45	4,3	T05	A	UMN TL	+	+	T05	+	0	+	+	+	BND	
17	Para	29	12,3	T05	A	UMN TL	+	+	T05	+	0	na	-	-	-	
18	Para	59	23,4	T08	A	UMN TL	+	+	T08	+	0	+	+	+	BND	
19	Para	28	0,9	T08	B	UMN TL	+	+	T06	+	0	na	+	+	-	
20	Para	82	17,3	T09	A	UMN TL	+	+	T07	+	0	0	+	+	-	
21	Para	40	22,0	T09	B	UMN TL	+	+	T11	+	0	na	+	+	Normal	
22	Para	38	16,4	T03	A	LMN TL	0	0	T03	0	0	na	0	0	Open	
23	Para	42	13,5	T08	A	LMN TL	0	0	T07	0	0	na	0	0	Open	
24	Para	35	11,8	T08	A	LMN TL	0	0	T07	0	0	na	0	0	Open	
25	Para	31	10,0	T08	A	LMN TL	0	0	T07	0	0	na	0	0	Open	
26	Para	63	38,4	T09	A	LMN TL	0	0	T07	0	0	na	0	0	Open	
27	Para	68	17,3	T09	A	LMN TL	0	0	T07	0	0	na	0	0	Open	
28	Para	56	23,9	T09	A	LMN TL	0	0	T09	+	0	na	+	+	Open	
29	Para	41	14,2	T09	A	LMN TL	0	0	T09	0	0	na	0	0	-	
30	Para	29	11,1	T10	A	LMN TL	+	+	T09	0	0	na	+	+	Open	
31	Para	74	43,7	T12	A	LMN TL	0	0	T10	0	0	na	0	0	Open	
32	Para	31	10,5	T12	A	LMN TL	0	0	T09	0	0	na	0	0	Open	
33	Para	50	20,2	T12	A	LMN TL	0	0	T09	0	0	na	0	0	Open	
34	Para	57	11,7	T12	A	LMN TL	0	0	T09	0	0	na	+	+	Open	
35	Para	36	7,0	T12	A	LMN TL	0	0	T09	0	0	na	0	0	-	
36	Para	28	6,6	T12	B	LMN TL	0	0	T09	0	0	+	+	+	Open	
37	Para	48	15,8	T12	A	LMN TL	0	0	T09	+	0	na	+	+	Open	
38	Para	63	24,6	L2	B	Intact TL	+	+	-	+	-	na	+	+	Normal	

Table 2 (continued)

SCI	Age	Evol	Level	AIS	Group	Dartos			Autonomic reflexes		Erection		Ejaculation	Orgasm	Bladder	
						Scrotum	Penis	Cremaster	Encephalic	Spinal	Psychogenic	Reflex			Contraction	Neck
39	Para	51	26,7	L3	B	Intact TL	+	+	T11	+	+	+	+	+	+	BND
40	Para	53	42,5	L3	A	Intact TL	+	+	-	+	+	+	+	+	+	BND
41	Para	66	27,9	L3	A	Intact TL	+	+	T11	+	+	+	+	+	+	BND
42	Para	49	26,1	L3	C	Intact TL	+	+	T11	+	+	-	+	+	+	Normal
43	Para	70	35,9	L3	A	Intact TL	+	+	T11	+	+	+	+	+	+	Normal
44	Para	42	20,6	L3	B	Intact TL	+	+	T11	+	+	+	+	+	+	Normal
45	Para	29	12,3	L4	D	Intact TL	+	+	T12	+	+	+	+	+	+	BND
46	Para	59	28,8	L5	C	Intact TL	+	+	T12	+	+	0	+	+	+	Normal

SCI spinal cord injury, Tetra tetraplegia, Para paraplegia, UMN upper motor neuron, LMN lower motor neuron, TL thoraco-lumbar, na non-applicable, BND bladder neck dyssynergia. Evol: time since injury; level: single-neurological level of injury; "+": present; "0": absent; "-": not tested

Electronic 2500 C (MMS) device. The bladder was considered to contract if the detrusor contraction exceeded 10 cm H2O (in accordance with the recommendations of the International Continence Society) [15].

Cystourethrograms were usually performed just after the urodynamic study. During bladder filling, the bladder neck can be normally closed, or it can be open. During bladder contraction, the bladder neck can either open normally or contract actively, indicating bladder neck dyssynergia.

Analysis of results

Patients were divided into three groups, depending on the level of lesion and integrity of the T11-L2 segment (Fig. 3):

- UMN TL: supraconal lesion above T10, the T11-L2 segment is intact within the UMN syndrome;
- LMN TL: the T11-L2 segment is within the LMN syndrome, the LMN lesion extends below L2 or above T11;
- Intact TL: conus medullaris, the T11-L2 segment is intact above the lesion;

Comparisons of qualitative values were performed using a χ^2 test.

Results

Patient characteristics are presented in Table 1. Forty-six consecutive patients with SCI were enrolled. Mean age was 46.4 ± 14.8 years; mean time since the onset of SCI was 18.1 ± 10.1 years. Nine patients had tetraplegia, 37 had paraplegia. Five patients had incomplete motor lesions (AIS C or D), 2 with tetraplegia, and 3 with low paraplegia (lesions below L2); 41 had complete motor lesions (AIS A ($n = 34$) or B ($n = 7$): 19 in the UMN TL group, 6 in the intact TL group, and 16 in the LMN TL group. The latter group consisted of 7 patients with lesions above T10, and 9 patients with lesions between T10 and L2.

Table 2 provides full descriptive data for each patient. DRs of the scrotum were always present in the UMN TL (21/21) and the intact TL (9/9) groups (Table 3). Complete elevation occurred more frequently in the UMN TL (15/21) than in the intact TL group (2/7). By contrast, DRs of the scrotum and the penis were absent in all but one patient (15/16) in the LMN TL group ($p < 0.01$) (Fig. 4). DR sensitivity was 0.97, specificity 1.0, positive predictive value 1.0, and negative predictive value 0.94.

When present, the unilateral left and right DRs were always symmetrical. The DR of the penis and the CR were only present when the DR of the scrotum was present (Table 3).

Table 3 Dartos and cremasteric reflexes

	Dartos scrotum		Dartos penis		Cremaster	
	Present	Absent	Present	Absent	Present	Absent
UMN TL (<i>n</i> = 21)	21 Compl = 15, Inc = 6	0	21 Compl = 11, Inc = 10	0	21	0
Intact TL (<i>n</i> = 9)	9 Compl = 2, Inc = 7	0	8 Compl = 0, Inc = 8	1	9	0
LMN TL (<i>n</i> = 16)	1 Compl = 0, Inc = 1	15**	1 Compl = 0, Inc = 1	15**	1	15**

UMN upper motor neuron, LMN lower motor neuron, TL thoraco-lumbar, Compl complete, Inc incomplete

***S* (*p* < 0.01)

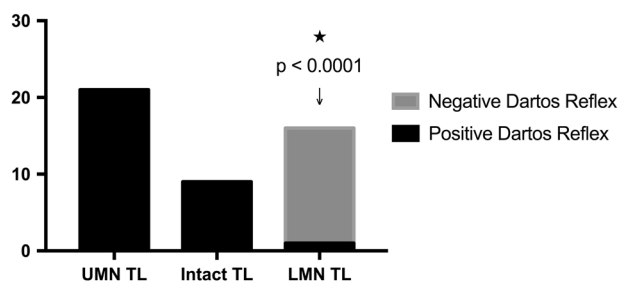


Fig. 4 Dartos reflex as a function of the integrity of the T11-L2 spinal segment. UMN upper motor neuron, LMN lower motor neuron, TL thoraco-lumbar

Presence of the DR was significantly ($p < 0.01$) associated with presence of ejaculation (mostly antegrade), type of bladder neck function (normal opening vs. bladder neck dyssynergia), and presence of autonomic spinal reflexes in the lower limbs. Inversely, absence of the DR was significantly ($p < 0.01$) related to a lower rate of ejaculation (only retrograde), an open flaccid bladder neck, and absent autonomic spinal reflexes. There was no statistical significance between presence of the DR and psychogenic erection ($p = 0.34$) or orgasm ($p = 0.74$) (Table 4).

Sympathetic vasomotor responses were normal (down to T11–T12) in the intact TL group, and extended between T3 and T11 in the LMN TL and the UMN TL groups. Spinal autonomic reflexes of the legs were always present in the intact TL and the UMN TL groups, and absent in all but 2 patients in the LMN TL group.

Table 5 shows findings related to the sacral cord. All but three patients in the UMN TL and intact TL groups (who all had an UMN syndrome), presented reflex erections and bladder contractions. In the LMN TL group with lesions above T10, reflex erections and bladder contractions were mainly absent ($p < 0.01$).

Discussion

The DR is a somato-autonomic reflex that depends on the integrity of the T11-L2 sympathetic segment. It has been shown in rats that the dartos muscle receives a functional sympathetic innervation and contracts to noradrenaline via

alpha-adrenoceptors. Contractile responses are stronger at lower temperatures (30° vs. 40°C) [16].

In monkeys, stimulation of the hypogastric nerve as well as the sympathetic chain produces penile retraction and enlargement of the corpora cavernosa [17]. In humans, contraction of the dartos has been reported as a side effect of Yohimbine, used in the treatment of erectile, ejaculatory or orgasmic dysfunction [18]. Other side effects include increased pulse rate and blood pressure, palpitations, tremor of the hands, facial flushing, anxiety, malaise, and headache. These sympathetic reactions are similar to the side effects of midodrine, used to enhance PVS in men with SCI [19]. In our experience, dartos contraction and penile retraction occur commonly with PVS, and the reactions are even more pronounced if midodrine is administered to the patient (unpublished data). The dartos also contracts during electroejaculation in men with SCI [20], and during erection in normal men [21]. Our results confirm that the DRs are easy to elicit, and are useful for the assessment of the integrity of the T11-L2 segment since they were always present when the T11-L2 segment was intact above or below the lesion, and disappeared when this centre was injured. In this study, the DRs of the scrotum and of the penis were always triggered together, which is in keeping with the anatomical description of the dartos in the scrotum, extending to the penile shaft [9].

The CR is another reflex that originates from the T11-L2 segment and shares the same afferent innervations as the DR, through the genitofemoral nerve. It is thus not surprising that both reflexes were either present or absent together. However, these scrotal reflexes must not be confused with each other. The CR produces a brisk elevation of the testis, while the DR triggers a slower elevation with concomitant wrinkling of the scrotum [6, 9]. The CR is a somato-somatic reflex with a short latency of 30–40 ms, which differs from the 1.6–11 s latency of the DR, a somato-autonomic reflex [10, 12]. The DR is thus more specific for the assessment of the integrity of the T11-L2 sympathetic centre than the CR. In our experience, the DR is more reliable than the CR, which is sometimes difficult to trigger, and is exhaustible. It may also be absent in various conditions such as hydrocele or varicocele, following

Table 4 Correlation between Dartos reflex and autonomic functions

Dartos	T11-L2 status (n = 46)		Psychogenic erection (n = 42)		Ejaculation (n = 38)		Orgasm (n = 21/23)		Bladder neck (n = 39)		Autonomic spinal reflexes (n = 45)		
	Intact or UMN	LMN	Present	Absent	Present	Absent	Present	Absent	Normal	Dyssynergia	Open	Present	Absent
Present	30	1	11	18	19	4	14	3	11	15	1	30	1
Absent	0	15	7	6	4	11	3	1	-	-	12	2	12
	S (p < 0.01)		NS (p = 0.34)		19A = 13, M = 2, R = 4	4A = 0, M = 0, R = 4	NS (p = 0.74)		S (p < 0.01)	S (p < 0.01)		S (p < 0.01)	

UMN upper motor neuron, LMN lower motor neuron, TL thoraco-lumbar, A antegrade, R retrograde, M mixed

Table 5 Findings related to the sacral segment

	Reflex erection		Bladder contraction	
	Present	Absent	Present	Absent
UMN TL (n = 21)	17	1	20	1
Intact TL (n = 9)	6	1	9	0
LMN TL (n = 16)	4	12**	6	9**
Above T10 (n = 7)	0	7	1	5
At T11-L2 (n = 9)	4	5	5	4

UMN upper motor neuron, LMN lower motor neuron, TL thoraco-lumbar

** : S (p < 0.01)

orchitis or epididymitis, or following testicular or inguinal (hernia) surgery, as well as in elderly males [6, 9].

Injury of the corticospinal tract usually gives rise to an UMN syndrome. The spinal cord reacts, unrestrained from supraspinal inhibitory influences, with complex efferent somatic and autonomic responses (mass response). Exaggerated deep tendon reflexes and muscle spasticity usually develop together with autonomic mass responses, including exaggerated pilomotor (horripilation) or sudomotor (sweating) reflexes or autonomic dysreflexia (lesions above T6) [22]. The DR observed in this study follows the same pattern: the response was incomplete (normal) when the T11-L2 segment was intact above the lesion, and complete (exaggerated) when T11-L2 was intact below the lesion within the UMN isolated spinal cord. The DR can be used as a marker of excitability of the isolated spinal cord.

This is the first report to show that the presence or absence of a simple reflex, the DR, is predictive of the functional status of the T11-L2 sympathetic spinal segment. Presence of the DR was strongly related to an intact T11-L2 segment, either above or below the lesion, whereas it was always absent in LMN lesions involving the TL segment. The results of this series are clinically relevant for the assessment of autonomic functions, particularly sexual and bladder function. Ejaculation (mostly antegrade) occurred significantly more frequently with PVS if the DR was present, while men with an absent DR were poor responders to PVS, and only retrograde ejaculation occurred, if at all. Urinary continence and effectiveness of bladder emptying were also partly related to the T11-L2 integrity: during detrusor contraction, the bladder neck either opened normally or was dyssynergic (with increased post void residuals) if the DR was present, while there was a high risk of an open bladder neck during bladder filling when the DR was absent. UMN syndrome, not DR, was predictive of the capacity for reflex erection and bladder contraction, since these reflexes depend on the integrity of the sacral segments (Fig. 1). Orgasm is a physical and emotional entity,

experienced at the peak of sexual arousal, often, but not always, accompanied by ejaculation. In males with SCI, many interconnected factors influence the possibility of orgasm, such as the level and severity of the lesion, the degree of autonomic stimulation and the occurrence of ejaculation. Thus presence of the DR and integrity of the T11-L2 segment are insufficient to predict the possibility of orgasm [5, 23, 24]. Finally, psychogenic erection relies on connexions between an intact T11-L2 centre and the brain. Previous studies established that preserved light touch and pinprick sensations in the T11-L2 dermatomes or sympathetic skin responses on the feet were predictive of psychogenic arousal potential in men [25, 26]. In this study, the lack of a significant relationship between the DR and psychogenic erection can be attributed to the inclusion of men with complete UMN lesions above T10.

Conclusion

A comprehensive clinical neurological examination, including somatic and autonomic responses is key to determine the functional potential of each person with SCI, particularly regarding their sexual responses [5]. The DR is quick and easy to test at the bedside and provides valuable information on the integrity and excitability of the T11-L2 sympathetic spinal segment. As such, we feel that DR should be considered as an addition to the autonomic standards in its future revision. Further prospective studies should confirm the potential of DR for the prediction of sexual and bladder neck function in men.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

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