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ORIGINALS

Urethro-Vesical Function During Spinal Shock

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Summary. Twenty spinal shock patients were investigated with simultaneous urethrovesical, anal and rectal pressure recordings and EMG of the external urethral and anal sphincters. "Dynamic" and "static" urethral pressure profiles (UPP) were carried out with empty and full bladder. Bladder filling was accompanied by an increased resistance in the "internal sphincter" zone, which in turn was paralleled in the majority of cases by an elevation of pressure in the membranous urethra without concomitant increase of its EMG activity. This is suggestive of an increased sympathetic activity in the bladder neck area and in the smooth muscle component of the external urethral sphincter. "Dynamic" pull-through UPP's displayed higher resistances in the membranous urethra than "static" interrupted UPP's pointing to the role played by the urethral mucosal receptors in eliciting artefactual results. Higher pressures were recorded in the juxtabulbar portion of the membranous urethra than in its mid portion pointing to a gradient of pressure within the external urethral sphincter itself. The amount of EMG activity recorded in the anal and urethral sphincters at "rest" was somewhat decreased; high pressures and distinct reflex activity were recorded in both sphincters showing that they escape spinal shock characterized primarily by areflexia. After defining spinal shock a rational explanation based upon neuroanatomical and neurophysiological findings is offered as to why somatic activity of the sacral segments escapes it as evidenced by clinical, urodynamic, and electromyographic recordings.

Key words: Neurogenic bladder - Spinal shock - Urodynamics - Electromyography - Smooth muscle - Striated muscle.

INTRODUCTION

Detrusor areflexia and hypotonia have been well documented in patients with spinal shock (36, 41). However, there have been but a few studies to determine the effect of spinal shock on the detrusor urethral unit as such (1, 9, 23, 27, 44). Most of these studies have adopted the urethral pressure profile (UPP) technique described by Brown and Wickham (8) and subsequently modified by Awad et al. (2).

It has been reported that urethral pressure profiles were either normal (1), unchanged (27), or reduced (6, 23), and electromyogram activity of the pelvic floor muscles was described either as absent (13), poor (23), or both (9).

Impulses originating from urethral mucosal receptors play an important role in the reflex activity of the pelvic floor muscles (5, 42). Whether those reflexes are affected during spinal shock remains to be seen. A possible relation between activities of the conus reflexes, UPP, and concomitant electromyogram patterns in the external urethral and anal sphincters warrants a close study in a sizeable group of spinal shock patients.

MATERIALS AND METHODS

Twenty male spinal cord injury patients with complete and incomplete lesions were studied (Tables 1 and 2). Eleven of these patients were admitted to the West Roxbury Veterans Administration Medical Center, Spinal Cord Injury Service, less than 24 hours post-injury, five within 48 hours, three within 3 to 5 days of injury and one on the 23rd day of injury.

Synchronous cystosphincterometrograms were carried out in 12 patients within 1 to 4 days post-

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injury, in 7 patients within 5 to 13 days post-injury, and in one patient on the 28th day post-injury. With the exception of a 64 year old paraplegic, all other 19 patients were between 17-39 years of age, average 24. Seventeen of the 18 patients with a complete neurological lesion were in true spinal shock as evidenced by deep tendon areflexia below the level of the injury. Two other patients had only partial deep tendon reflex activity of recent onset and were considered to be still in the acute stage of injury and were, therefore, included in this series. Daily complete neurological examination was carried out by one of us (ABR) until and including the day of the examination. Presence or absence of deep tendon reflexes below the level of the injury and conus reflexes were especially looked for.

The urodynamic investigations consisted of "dynamic" and "static" urethral pressure profiles with concomitant vesical and anal pressure recordings and EMG of the external anal and urethral sphincters. In addition in 7 patients the pressure in the external anal sphincter was also measured. Patients were lying supine with about 15 degrees of pelvis obliquity as to allow adequate visualization of the entire urethra. The study was monitored by an image intensifier, soundtracked and videotaped as indicated. Patients had their bowel emptied the day before the examination or in the morning before. Fluids were restricted 3-4 hours before the time of examination. The bladder was emptied before beginning the study. All but two patients had sterile urine at the time of the examination. The pressure recordings were done by means of P23 DB Statham gauge transducers[1] connected to a polygraph[2] consisting of 6 carrier preamplifiers and a direct writing recorder. The transducers were zeroed in at the level of the symphysis pubis. Urethral pressure profile variations in the range of 2.5-5.0 cm water corresponding to 1 mm and 2 mm paper deflection, respectively, were considered to be within possible margins of errors and were not taken into account in the analysis of results.

Assumed equal to abdominal pressure, intrarectal pressure changes were obtained from a custom made flaccid balloon condom loosely taped over the end of a 10 FG[3] plastic tube. The balloon was filled with 5 cc water and zeroed in the rectum as to record only relative pressure variations and not the absolute true intrarectal basic pressure. The intrarectal pressure is electronically substracted from the intravesical pressure as to display the "true" intracystic pressure.

Urethrovesical and external anal sphincter pressure recordings were obtained by a 10 FG trilumen plastic catheter and a water filled dumbbell balloon plastic catheter, respectively, devised by one of us (ABR)[4]. One of the two channels terminating at the tip of the trilumen catheter was utilized for recording the intravesical pressure while the bladder was being filled through the other with radiopaque material [5] mixed with nitrofurantoin [6] and distilled water as to obtain 450 cc of this solution. The third lumen of the catheter communicated to the outside through two 'one-millimeter' openings adjacent to a radiopaque marker located 15 cm away from the other radiopaque marker at the catheter tip (Fig. 1). By incorporating a strain gauge pressure transducer in the infusion pump catheter assembly, these openings were used for urethral pressure recordings during constant intraurethral infusion. The urethral marker indicated its anatomical location and the corresponding pressure. The physical factors involved in the interpretation of this technique have been analyzed previously (55). Two Harvard infusion pumps [7] were used for bladder filling and urethral infusion at the constant rate of 4 cc and 2 cc per minute, respectively. During UPP measurements, however, bladder filling was interrupted.

Synchronous cystourethrometrographic studies were carried out with continuous bladder pressure recording whereas the radiopaque urethral marker was successively positioned under fluoroscopy at the vesicourethral junction (VUJ), the prostatic urethra (U1), the mid membranous urethra (U2), the distal part of the membranous urethra (U3), and the bulbous urethra (U4) (Fig. 2). The location of these regions in relation to the anatomical landmarks of the bony pelvis has been previously described (43).

In 14 patients these regions were individually studied with two different techniques. A urethral pressure profile with continuous manual withdrawal of the catheter (8) - about 1 cm per 5-10 seconds - was first obtained, the so-called withdrawal "dynamic" urethral pressure profile. It was followed by a "static" urethral pressure profile. This latter technique consisted of interrupted pulling of the catheter out of the bladder by placing the radiopaque urethral marker alternatively into each of the locations to be analyzed, starting with the VUJ (Fig. 3). At each step one to two minutes were allowed for pressure equili-

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[4] Portex Limited, Hythe, Kent, England CT 21 6JL

[5] Reno-M-Dip™ 30 Per cent, E. R. Squibb & Sons, Inc., New York, New York, USA

[6] Furacin solution, 60 cc, Eaton Laboratories, Norwich, New York, USA

[7] Harvard Apparatus Company, Inc., Millis, Massachusetts, USA

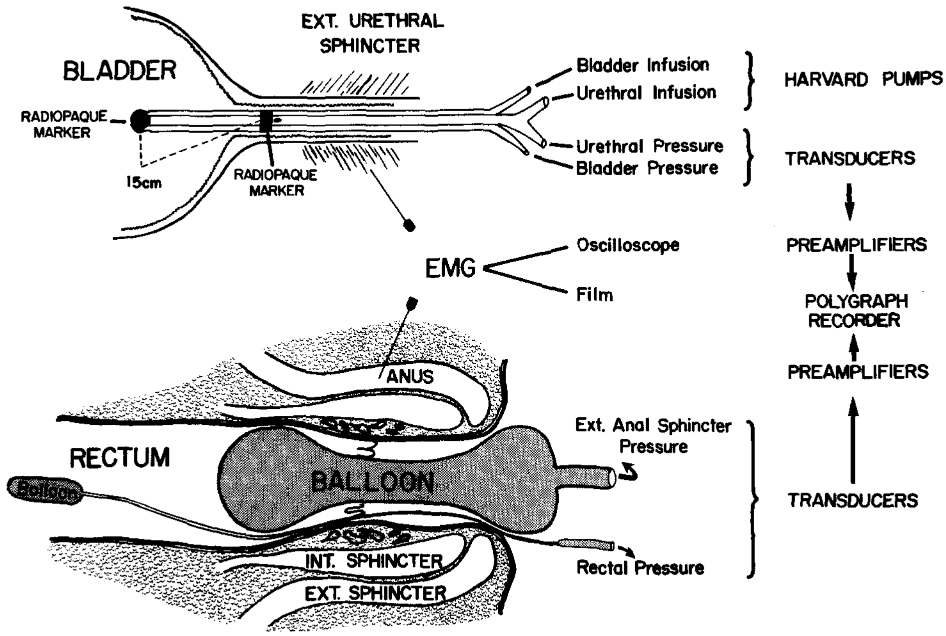

Fig. 1. Diagrammatic schema of trilumen catheter-pumps-balloons-transducers assembly

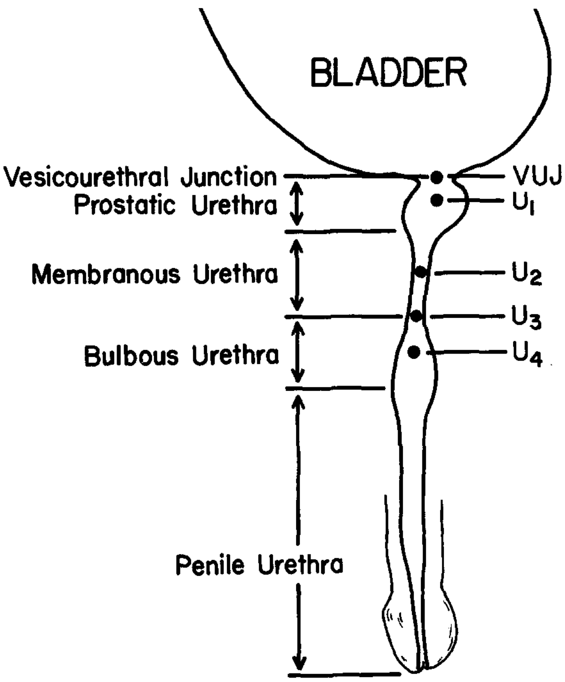

Fig. 2. "Static" urethral pressure profile locations. Diagrammatic representation of the various urethral segments to be investigated

bration until a stable base line was obtained. In U2 and U3 it was found that 3-4 minutes were often needed until the pressure stabilized. Once a stable pressure was obtained in a given location procedures such as Credé maneuvre, bulbocavernosus reflex (BCG), tapping the bladder, or administration of drugs were evaluated. "Dynamic" versus "static" pressure profile recordings with empty and full bladder were obtained in each of those 14 patients.

In 15 patients EMG studies of both urethral and anal external sphincters were performed with a two-channel custom built electromyograph[8] which had been incorporated into the polygraph by the manufacturer[9]. This combination allows for synchronization of pressure recordings on the polygraph paper and EMG tracings on the camera film. An events marker has been devised such as to yield a simultaneous display of the recording on the polygraph paper and on the oscilloscope and hence on the light sensitive camera film which photographs the slave CRT through a series of lenses. This allows for accurate instantaneous reproduction and pressure related EMG analysis of any event taking place during the examination.

Electromyogram recordings were obtained with coaxial needles[10]. Urethral and anal needles 65 mm and 30 mm long and 0.65 mm and 0.45 mm in diameter, respectively, were used. As first described by Giovine (18) a finger in the rectum located the apex of the prostate and guided the urethral needle which was inserted through the

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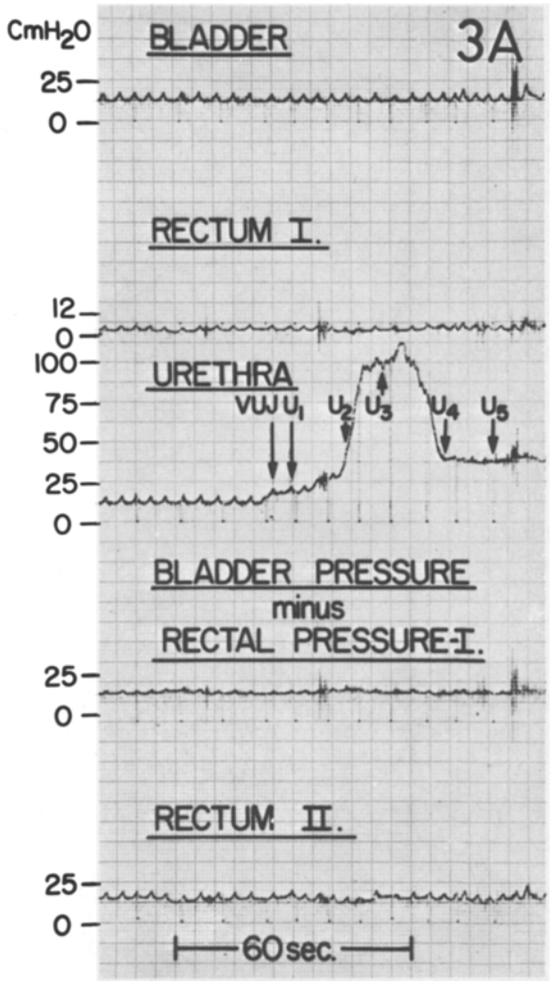


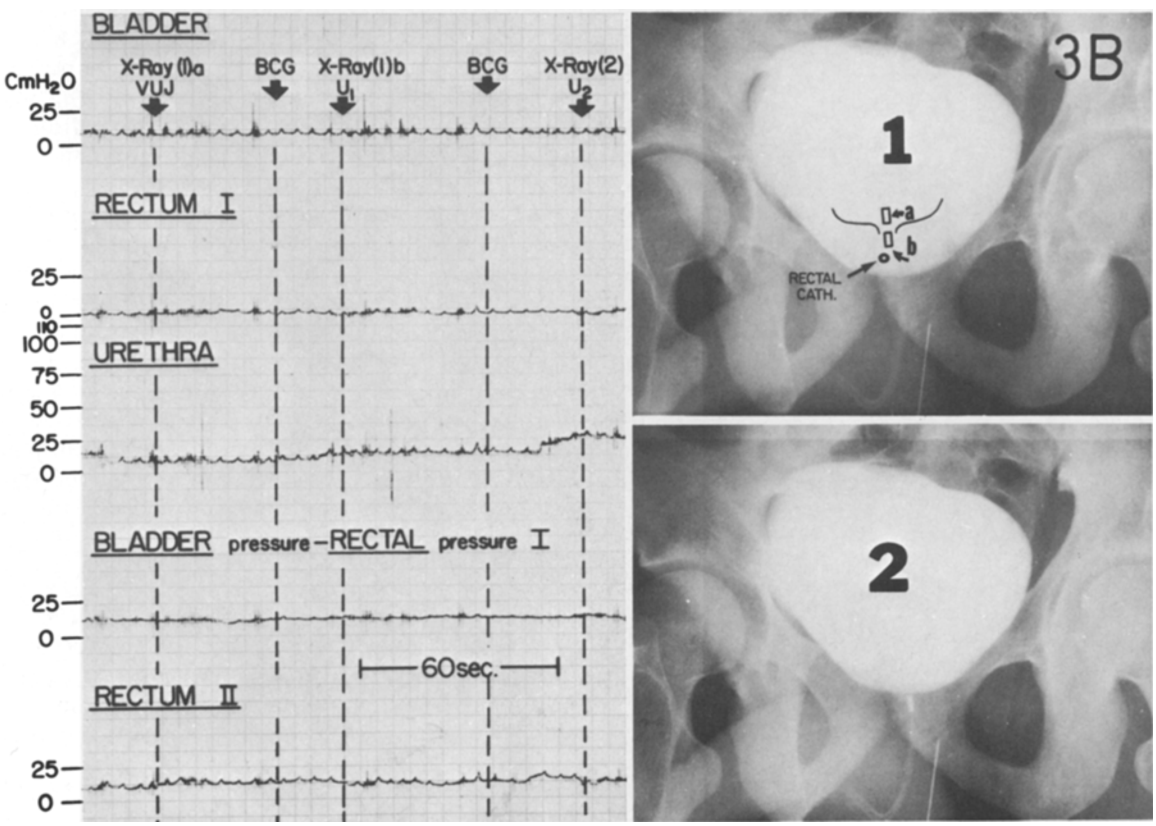
mid-line of the perineum 2-3 cm in front of the anus. Then the anal needle was inserted usually into one of the lateral halves of the external anal sphincter, 1-2 cm deep, according to the thickness of the muscle. The penetration of either needle into the corresponding muscle was followed by ultrasound and fluoroscopy.

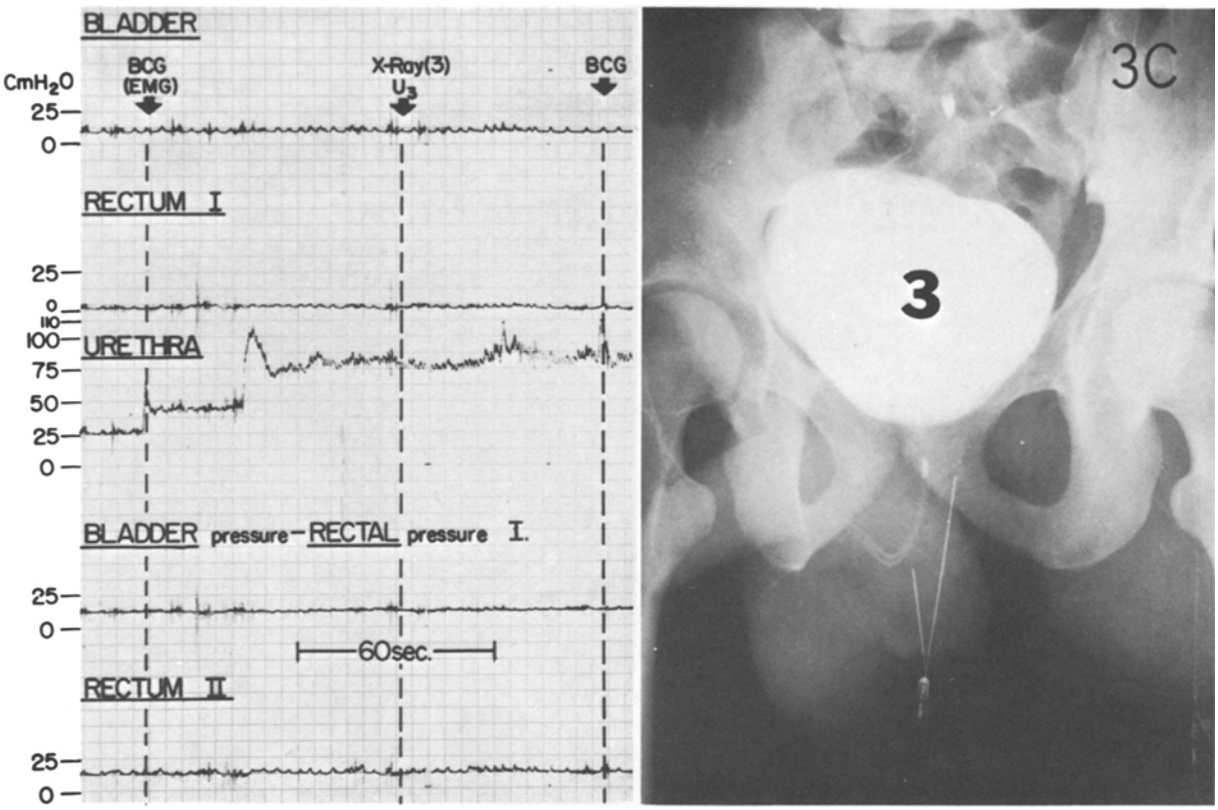
RESULTS

Apart from 2 patients who had early return of some deep tendon reflexes, all others had none below the level of injury. It is, however, remarkable that all patients had one or more conus reflexes present (bulbocavernosus reflex, anal wink or anal tone). While the anal tone was present in all patients, the BCG was absent in four, the anal wink in three patients, while both were absent in one patient (Tables 1 and 2).

With an empty bladder, "dynamic" UPP usually displayed about 30 per cent higher values than indicated by "static" profiles at the external sphincter zone. This was the case in 10 out of 14 patients (Fig. 3 A and C). In the other four patients, readings were identical.

In 17 spinal shock patients evaluated with "static" UPP, the external sphincter zone displayed higher pressures at U3 than U2 in eleven, equal pressures in three and lower pressures in three. Average pressure recorded at U3 was





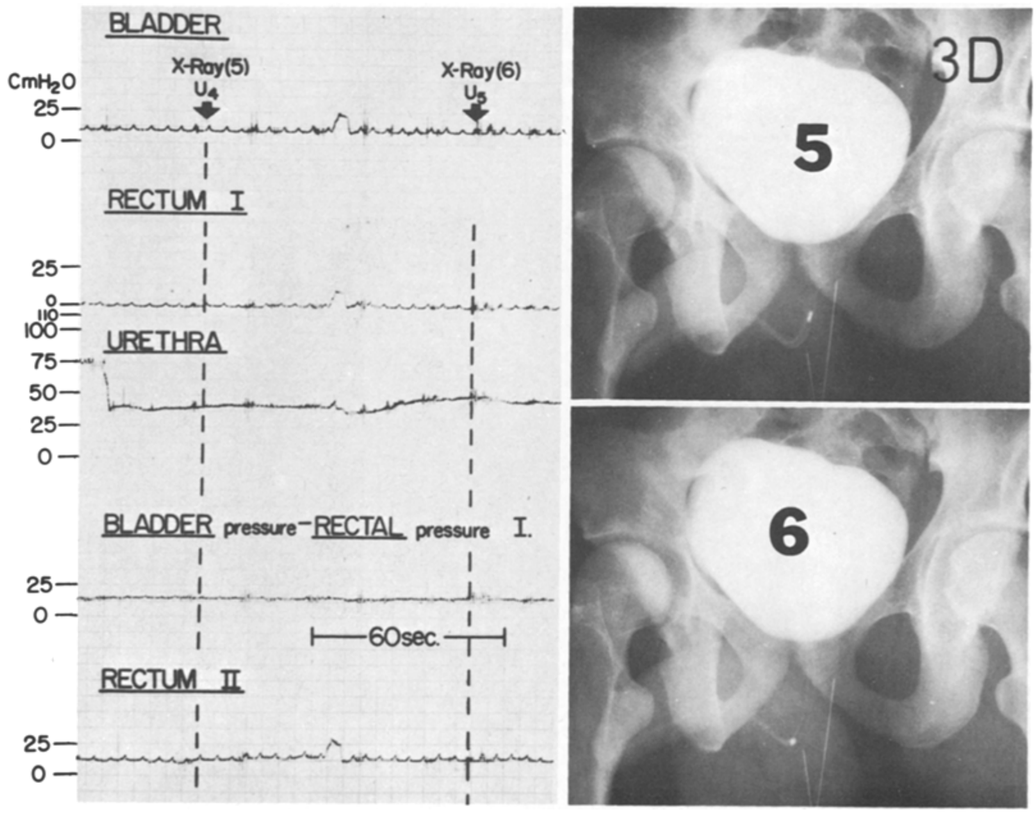


Fig. 3 A-D. Patient number 9. Complete tetraplegia C7 in spinal shock. A "Dynamic" UPP. Intrarectal pressure recording I is a zeroed in pressure to display only relative changes of intrarectal pressure. Intrarectal pressure recording II is zeroed in outside the rectum to reflect the true intrarectal pressure. The maximum urethral closing pressure in U3 is 100 cm water. B "Static" UPP with radiographic controlled pressure measurements in VUJ, U1, and U2. BCG is negative in VUJ and in U1. C "Static" UPP with pressure measurements in U2 and in U3. BCG is positive in U2 (EMG) and in U3. The maximum urethral closing pressure in U3 is 80 cm water vs. 100 cm water in the "dynamic" UPP. D "Static" UPP with pressure measurements in U4 and in U5 -first bend of the urethra

Table 1. Clinical information and cystosphincterometrographic data in 17 spinal shock patients

Patients	Days post-inj. CMG	Bladder volume	Bladder pressure	X-rays bladder neck	VUJ	U_1	U_2	U_3	U_4	Conus reflexes
1. W. H. 29yrs. C_6 Compl.	5	100 400	5 10	Closed	15 15	20 20	75 70	45 -	40 35	BCG: + A. Tone: 2 A. Wink: +
2. H. R. 19yrs. T_5 Compl.	1	100 250	7 8	Closed	25 -	- 25	- 75	- 70	45 50	BCG: ++ A. Tone: 3+ A. Wink: +
3. M. C. 64yrs. T_4 Compl.	12	100 300	2 7	Closed	20 37	35 37	35 35	62 65	10 12	BCG: neg. A. Tone:1+ A. Wink: +
4. L. M. 29yrs. C_6 Compl.	28	50 300	2 7	Closed Slightly Funneled	5 7	12 12	40 37	48 52	- -	BCG: neg. A. Tone: 2+ A. Wink: +
5. K. R. 21yrs. C_8 Compl.	6	150 450	2 10	Closed	18 15	18 15	55 58	80 80	25 32	BCG: ± A. Tone:3+ A. Wink:neg.
6. F. T. 29yrs. C_7 Compl.	1	100	2	Closed	17	22	37	50	35	BCG: neg. A. Tone:2+ A. Wink:neg.
7. D. H. 22yrs. C_7 Compl.	2	50 350	2 2	Closed	8 10	27 37	90 110	50 50	60 45	BCG: ++ A. Tone:3+ A. Wink: +
8. H. A. 17yrs. C_5 Compl.	3	50 400	2 7	Closed	10 20	10 37	50 65	62 65	32 -	BCG: ± A. Tone:2+ A. Wink: +
9. McG. J. 18yrs. C_7 Compl.	4	300	10	Slightly Funneled	14	14	25	80	45	BCG: ± A. Tone:1+ A. Wink: +
10. V. J. 22yrs. C_4 Compl.	3	30 350	5 12	Closed	5 17	12 17	75 75	75 -	40 37	BCG: ++ A. Tone:3+ A. Wink:neg.
11. McK. L 18yrs. C_4 Compl.	2	50	2	-	25	25	95	75	35	BCG: ± A. Tone:3+ A. Wink: +
12. A.D. 23yrs. C_6-C_7 Compl.	4	50 350	2 4	Slightly Funneled	2 4	6 12	75 100	80 80	- -	BCG: ± A. Tone:2+ A. Wink: +
13. G. R. 33yrs. C_6 Compl.	4	50 300	2 5	Slightly Funneled	10 7	10 12	50 60	62 60	30 30	BCG: ± A. Tone:1+ A. Wink: ±
14. O.D. 27yrs. C_4-C_5 Compl.	4	50 400	2 5	Slightly Funneled	2 5	2 9	55 70	75 85	35 -	BCG: ± A. Tone:2+ A. Wink: ±
15. H. R. 39yrs. T_4-T_5 Compl.	4	50 400	2 8	Slightly Funneled	2 8	10 15	35 60	50 62	- -	BCG: ± A. Tone: 2 A. Wink: ±
16. Sm. Th. 21yrs. C_6-C_7 Compl.	9	50 500	3 15	sl. Funneled Closed	3 15	14 25	48 65	75 85	50 -	BCG: - A. Tone: 2 A. Wink: +
17. C. C. 21yrs. T_4-T_5 Compl.	13	50 300	3 7	Closed	3 7	15 25	50 50	90 90	- -	BCG: ++ A. Tone: 2 A. Wink:++

Table 2. Clinical information and cystosphincterometrographic data in 3 patients partially out of spinal shock

Patients	Days post-inj. C.M.G.	Bladder volume	Bladder pressure	X-rays: bladder neck	VUJ	U_1	U_2	U_3	Conus reflex	Remarks
18. T.H. 23yrs.		50	2	Slightly Funneled	2	20	45	45	BCG: +	Upper motor neuron bladder
L_1 Compl.	9								A.Tone: 2	
Epiconal Lesion		300	5		-	-	-	45	A.Wink: +	
19. L.J. 17yrs.		50	2	Slightly Funneled	7	7	32	62	BCG: ±	
C_7 Incompl.	3				-	-	32	70	A.Tone: 2	Patients partially out of spinal shock.
Ant. Cord Syndr.		300	8						A.Wink: +	
20. G.R. 23yrs.									BCG: +	Upper motor neuron bladder out of shock: I.W.T. +
C_4-C_5 Incompl.	11	50	5	Open	5	12	50	75	A.Tone: 2+	
Ant. Cord Syndr.									A.Wink: +	

Table 3. Comparative data obtained from static UPP measurements in 13 patients during and after spinal shock. Higher values can be seen in U2 and in U3 in 7 patients and in U3 alone in 2 patients after spinal shock dissipated. Patients numbers refer to "clinical information" mentioned in Table 1

In spinal schock				Out of spinal schock		
Resistance in CmH_2O		Days post-inj.	Pts. no.	Resistance in CmH_2O		Wks. post-inj.
U_2	U_3			U_2	U_3	
37	50	1	6	200	125	15
75	75	3	10	125	110	16
95	75	2	11	125	120	16
75	80	4	12	85	95	12
50	62	4	13	62	100	13
55	75	4	14	75	100	12
35	50	4	15	95	85	12
75	45	5	1	80	52	10
55	80	6	5	50	87	36
50	62	3	8	55	67	11
48	75	9	16	45	70	13
35	62	12	3	40	80	10
40	48	28	4	35	65	20

about 70 cm water, while at U2 it was about 60 cm water.

In 13 of our 17 patients where longitudinal studies were carried out after patients went out of shock and became spastic, higher values were recorded in U2 and/or U3 in nine patients, while they were unchanged in four (Table 3).

In 13 spinal shock patients, effects of bladder filling of up to 400 cc or more are shown in Table 1:

a. No decrease of pressure was noted in any area of the urethra examined.

b. While no change was noted in the internal sphincter zone in four patients, the rest (9) have shown increase in pressure in U1 (6), UVJ alone (1), or both (2). The increase of pressure averaged 8 cm water in U1.

c. In the external sphincter zone an average increase of pressure by 17 cm water was noted in U2 in seven patients, six of whom had a rise

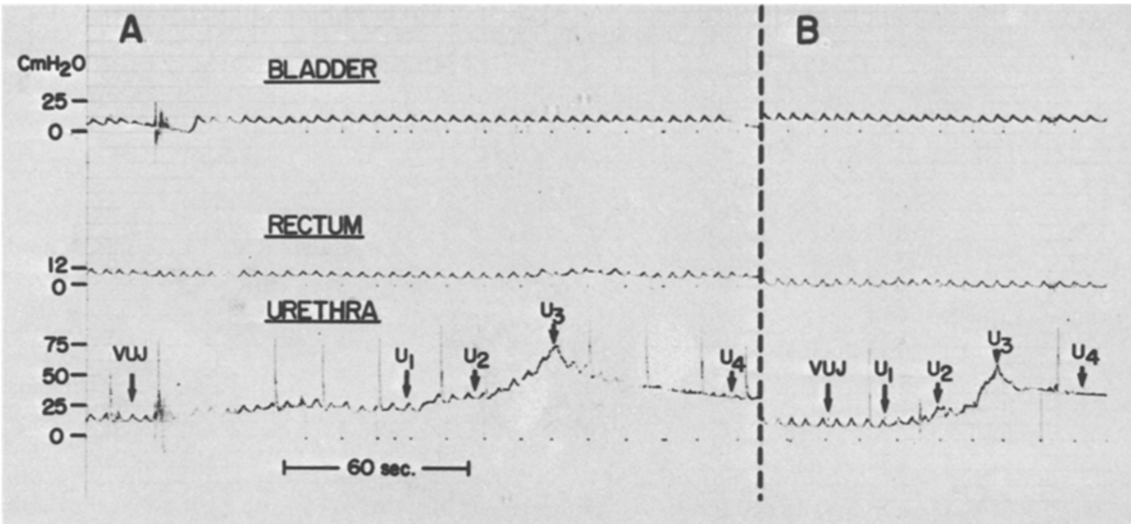


Fig. 4 A and B. Patient number 6. Complete tetraplegia C7 in spinal shock. "Dynamic" UPP. A Before the administration of an alpha-adrenergic blocking agent. B Thirteen minutes after the intravenous injection of 8 mg phentolamine the pressure has decreased by 13 cm water in U1 and in U3, and by 7 cm water in U2

in U1 pressure, while the rest (6) showed no increase in pressure. In U3, three patients showed a rise in pressure, all of whom showed a concomitant increase in pressure in U1 and U2; while in eight patients there was no increase in pressure, in four of those, however, there was an increased pressure in U1 and U2; in two patients the pressure was not recorded.

In two patients where 8 mg of phentolamine were administered intravenously, a drop of 25-50 per cent in UPP pressure was noted in the external sphincter zone (U2-U3) with concomitant drop in U1 in one patient (Fig. 4). In two other patients where 5 mg only of phentolamine were injected, no drop in pressure was noted.

Responses to the BCG were observed in most instances in both the anal sphincter as well as the external urethral sphincter as recorded by the anal balloon and the urethral catheter, respectively.

Needle insertion in both sphincters caused normal insertional activity with continued firing of motor units with an interference pattern of about 50 per cent in most cases. This returned to base line activity earlier than would usually be observed in normals or upper motor neuron lesions out of spinal shock. During "rest" there was a frequency of 3-7 action potentials per second the amplitude usually being 40-60 microvolts. In 3 of 15 patients no resting activity could be detected in either sphincter. The action potentials have essentially normal parameters except for some diminution of amplitude. Mean duration of potentials was found to be usually 4-5.5 milliseconds as in normals. During catheter insertion and coughing recruitment produced a 90 to sometimes 100 per cent interference pattern, with amplitudes ranging from 200 to 600 microvolts. After examination was continued for 10-15 minutes potentials seemed to decrease in amplitude or even disappear until the end of the recording. BCG responses were present in all patients but were noticeably different with a tactile response hand produced than with squeezing the glans penis with a Kelley clamp.

DISCUSSION

Spinal shock was first described by Hall (25) who stated "after division of the spinal marrow, the animal is under the influence of "shock", and the excitomotor power, with the reflex actions, are suspended for a time". Spinal shock should, therefore, be limited to the period of complete abolition of all tendon reflexes and profound depression of other reflex activity below the level of cord transection (30). This period varies considerably in its duration from one animal species to another (11, 46). Conus reflexes "BCG and anal reflexes" have been noted as early as a few hours after injury (17, 24, 30, 33, 34); this has also been our experience. Whether in fact they are ever abolished remains to be proven (52). The anal tone and the BCG responses recorded from the external urethral sphincter, though not mentioned by other authors, have been present in all our patients. Preservation of conus activities may be due to one or more factors based on anatomical and neurophysiological grounds:

a. A special clutch of cells were demonstrated by Onuf (38) in the anterior horns of the second sacral segment and extending into the distal part of the first and the proximal part of the third sacral segments. He suggested that this group of cells which he named group "X" and and were characterized by their small size might be thought of as a center for the vesical and rectal sphincters. A recent study has re-emphasized this possibility in showing that in patients with amyotrophic lateral sclerosis, vesicorectal sphincter functions remain intact until the late stages of the disease because of the remarkable preservation of this group of "X" cells (32). We propose that this group of cells is less influenced by spinal shock than the other large alpha-motoneuron cells.
b. Afferent impulses responsible for the EMG resting activity of the external anal sphincter seem to originate in the pelvic muscles themselves (40) apart from the role played by the cutaneous perianal receptors (5). Kawakami (28) has suggested that the spinalization character of the tonic elements of the external anal sphincter was stronger than the kinetic ones. This would explain the maintenance of the anal tone in all our patients whereas the anal wink and BCG were absent at times.
c. Unlike deep tendon reflexes, cutaneous polysynaptic reflexes do not depend on centrally modulated peripheral receptors and can be affected only at the afferent endings, interneurons or motoneurons (56). This could explain why the anal wink suffers less of shock depression than knee or ankle jerks.
d. The sudden removal of descending tonic excitatory pathways caused by transection of the spinal cord, the so-called "isolation-dystrophy" by Sherrington (46), produces relaxation of intrafusal muscle fibers through acute deficit of the muscle spindle control from the gamma-motoneurons (59); the deactivation of the gamma loop in turn deactivates the alpha-motoneurons thus producing spinal shock (3). Decreased fusimotor activity and depressed excitability of interneurons have also been described by others (12, 26, 47). However, very few muscle spindles have been described in the external anal sphincter in man (39, 53), whereas Gosling and Dixon (20) did not observe any in the external sphincter in male and female urethra. These findings represent an anatomical factor which could play a role in the relative insensitivity of these muscles to spinal shock.
e. Latency of the bulbocavernosus reflex was recorded from the external urethral and anal sphincters in response to stimulation of the glans penis in 2 patients in spinal shock (Fig. 5). Latencies of 30-40 milliseconds and the current threshold were similar to those reported in normals and in patients out of spinal shock (15, 45). Based upon those observations it would appear that spinal shock does not depress sphincters interneuron and alpha-motoneuron activity to a marked degree.

Afferents from bladder and urethral mucosal receptors play an important role in the reflex activity of the pelvic floor muscles of patients with chronic upper motor neuron lesions (5, 42). The continuous withdrawal "dynamic" UPP displayed about 30 per cent higher values than the interrupted "static" UPP at the external sphincter zone in most cases, because it stimulates more afferents from mucosal receptors. This is also substantiated by the enhanced EMG pattern observed and conversely by the similitude of tracings obtained from both techniques in lower motor neuron bladders. We have, therefore, given preference to "static" UPP over "dynamic" UPP in our evaluation. Furthermore, "static" UPP is carried out under fluoroscopic control and allows for accurate location of the radiopaque catheter marker in the urethra. The portion of the urethra wrapped by the external sphincter (U2) is the place of maximum pressure (31). Our findings present and past point to a higher pressure still at the juxtabulbar urethra -U3- (44), where greatest concentration of striated muscle fibers are to be found. This is in accordance with findings by Gil Vernet (51) and Uhlenhuth (50).

Experimental data have suggested that the "internal sphincter" contracts as the bladder is filled with urine (29, 49), and that the rise in intraurethral pressure following bladder filling in normals (19, 22) is mediated by the alpha-receptors of the sympathetic division of the autonomic nervous system (49). Evans (18) has shown in some cats more sympathetic discharge when the bladder was filling and Talaat (48) has brought evidence that the rise of intravesical pressure in dogs gave way to impulses which travel through the hypogastric and pelvic visceral nerves. An adrenergic response was found to be variable in the human bladder neck with an alpha-response to adrenergic agents in about 60 per cent of cases whereas this response was consistently present and strong in the posterior bladder neck composed predominantly of trigonal muscle (10), a region which has revealed numerous noradrenergic terminals (21).

Our findings in spinal shock patients are at variance with those of McGuire et al. (23) who showed no change in urethral pressure with bladder filling. Nine of 13 patients displayed an increased pressure in the "internal sphincter" zone with bladder filling, a finding also disclosed by others (1). This pressure increase was however most consistently found in U1 (6 patients). Concomitant with that increase of pressure in U1 those patients also showed an increase of pres-

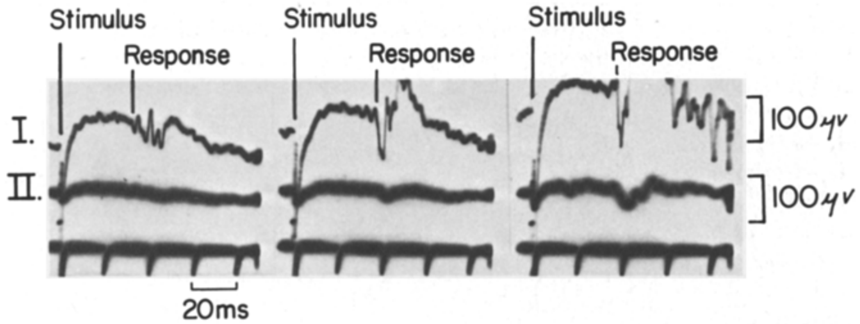


Fig. 5 A-C. Patient number 1. Complete tetraplegia C6 in spinal shock. Electrostimulation of the glans penis with EMG recordings from both the external urethral (1) and anal (II) sphincters. Duration and frequency of stimulus, 0.2 ms and 1 per second, respectively. A Threshold stimulus at about 75 volts. B Maximum stimulus at about 90 volts. C Supramaximum stimulus at 150 volts. Latency time: 38 ms

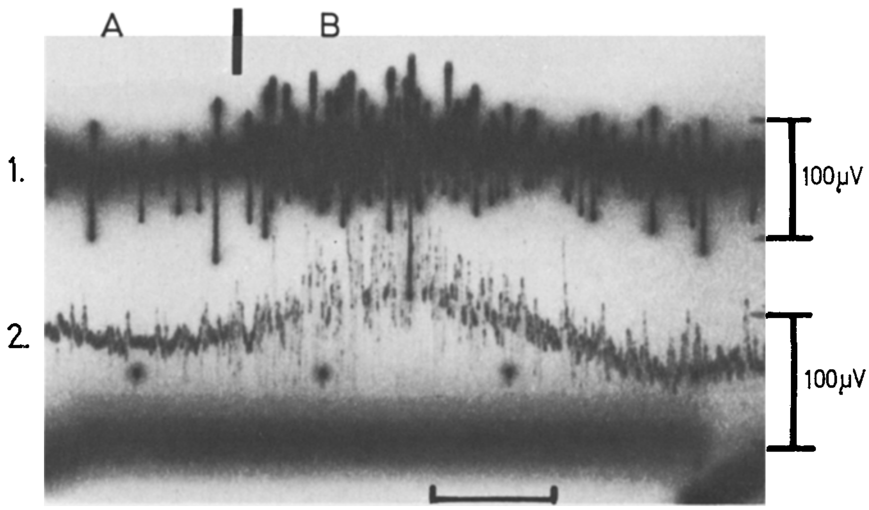


Fig. 6 A and B. Patient number 10. Complete tetraplegia C4 in spinal shock. EMG tracings from 1. external urethral sphincter and 2. external anal sphincter. Anal and urethral tracings are similar but appear to be different due to varying brillance of beams. A Base line; unusual amount of activity in both sphincters - for a patient in spinal shock- . B Response and after response to the bulbocavernosus reflex

sure in U2. Urethral sphincter relaxation secondary to bladder filling was never observed, possibly because low bladder pressures did not elicit impulses in afferent fibers in the pelvic nerves and failed to inhibit pudendal motoneurons (7).

Due to the intertwining of smooth and striated muscle fibers at bladder neck demonstrated anatomically and functionally (4, 54), it may be questioned which of the smooth or striated muscle components or a combination of both accounts for that increase of pressure in U1 and U2. The absent BCG in U1 in 5 of the abovementioned 6 patients but the markedly positive BCG in U2 in all 6 patients, the lack of simultaneous increased EMG activity in the urethral sphincter or even its diminution with bladder filling, and the marked decrease of pressure in U2 and U3 following the administration of an alpha-adrenergic blocking agent in 2 patients would lend support to the hypothesis of a predominant smooth muscle component in response to bladder filling. In spinal shock experiments, however, urethral reactions to bladder filling have been shown to occur with enhanced EMG activity of the pelvic floor muscles (14).

In the first of 2 patients to receive phentolamine the BCG was positive in the VUJ and U1, but the drug did not bring any change of pressure within either location. In the second patient the BCG was negative in the VUJ and in U1; the drug however decreased the pressure in U1 by 50 per cent. These results seem to point to lack of effect of phentolamine on the striated muscle and lead us tu conclude with others (35) that the pharmacologically induced pressure decrease noticed in U2 and U3 is secondary to a decreased activity in the smooth muscle component of the membranous urethra. In both of our patients the decrease of the maximum urethral closing pressure by 25 and 50 per cent, respectively is similar to Nordling's findings in neurological patients (37).

Increased UPP values have been found in U2 and/or U3 in 9 of 13 patients after they went out of spinal shock and became spastic (Table 3). These findings tend to support the fact that in spinal shock the striated component of the external urethral sphincter does not disclose its activity to its full extent. This is further evidenced by the EMG recordings of the external urethral and anal sphincters in shock patients which revealed low amplitude and frequent disappearance of potentials at "rest" in the majority of cases (Fig. 6).

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ADDENDUM. Since this paper was submitted for publication, three studies recently published have brought further evidence that the cell group X of Onuf is involved in the innervation of the muscles of the pelvic floor as they relate to recto-vesical functions.

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