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**SESSION ON URODYNAMICS AND ITS EFFECTS ON THE
TREATMENT OF THE NEUROPATHIC BLADDER
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**URODYNAMIC OBSERVATIONS ON PATIENTS WITH
SACRAL ANTERIOR ROOT STIMULATORS**

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Summary. The urodynamic changes produced by sacral anterior root stimulators have been assessed in 13 patients with spinal injuries. Before surgery all of the eleven men and two women had poor or absent bladder control with large residual volumes. Videocysto-urethrography with pressure and flow studies was performed pre-operatively and repeated once post-operatively, at intervals of 6 months to 5 years.

In all cases the residual volume was reduced to less than 50 ml and the functional bladder capacity increased to within the normal range. All the patients were able to void voluntarily by activating their implants in bursts. This produced an interrupted stream at normal voiding pressures and acceptable flow rates. There was definite improvement in vesico-ureteric reflux and decrease in bladder trabeculation following implantation of the stimulator.

Use of the stimulator has enabled nine of the patients to be continent at night. Eight of them are also dry during the day.

Key words: Urodynamics; Spinal neural injuries; Implant; Stimulator; Bladder; Sacral roots.

Introduction

REFLEX MICTURITION in patients with spinal injuries is inferior to normal micturition in four ways. It usually leaves a high residual volume; its spontaneous occurrence is difficult to predict; in some patients it is difficult or impossible to trigger artificially; and the outflow resistance is often abnormally high. The first of these faults is probably the main reason why urinary infections are common in patients with spinal injuries; the second and third faults cause the majority of them to be incontinent of urine, and to remedy the fourth fault, bladder neck resections and external sphincterotomies are often done, and may make the incontinence worse.

Brindley *et al.* (1982) described the use of sacral anterior root stimulators for bladder control in eleven patients with spinal injuries. All

TABLE I
Personal data

Patient number	Sex	Age at operation	Lesion	Follow-up (months)	Previous surgery	Appliances
1	M	38	T6	60	S × 2 + T	Catheter
2	M	38	T12	57	—	Condom
3	M	33	T9	49	—	Condom
4	M	43	C6	45	—	Condom
5	M	28	T10	42	—	Condom
6	F	41	T8(inc)	40	—	—
7	M	32	T5	31	S	Condom
8	M	24	T7	30	—	Catheter
9	M	27	C6(inc)	21	T	Condom
10	F	26	C6	16	—	Catheter
11	M	24	C6-8	12	—	Catheter
12	M	41	T12	8	T	Condom
13	M	37	T6	7	—	Catheter

S = external urethral sphincterotomy.

T = transurethral resection of bladder neck.

these patients had decreased urinary residual volumes after implantation of the stimulator and six became continent. The present paper reports urodynamic findings on the above eleven patients and the next two in series, i.e. on all patients with spinal injuries who have had sacral anterior root stimulators implanted at the Maudsley Hospital between April 1978 and September 1982 (Table I).

Methods

Before surgery, patients 3 to 13 were assessed by videocysto-urethrography with pressure and flow studies (Bates and Corney, 1971). The procedure used was as follows (patient was asked to attend with a full bladder): on arrival he/she was allowed to void in his/her normal fashion, e.g. suprapubic percussion, abdominal straining etc., seated on a Disa flowmeter. The patient was then transferred to an X-ray screening table and the bladder was catheterised transurethrally with a size 8 French catheter for bladder filling and a 1 mm polythene tube for bladder pressure measurement. The residual urine volume was measured. A 2 mm polythene tube, protected from faecal blockage by a condom, was inserted into the rectum for intra-abdominal pressure measurement. The two polythene tubes were connected to pressure transducers and the rectal pressure electronically subtracted from the intravesical pressure to give the actual detrusor pressure. All three were recorded on a chart recorder.

The bladder was filled with a radio-opaque medium (Diodone or Urografin) on at least two occasions. First, fast bladder filling was used (100 ml/min), so that the bladder could be radiologically screened through most of the filling phase. The bladder was then emptied and filled more slowly (30 ml/min) in order to assess detrusor activity and capacity more accurately. During bladder filling the patient was asked to report any sensation. When cystometric capacity was reached the filling catheter was

TABLE II
Preoperative urodynamic data

Patient number	Filling cystometry			Voiding		Screening			
	Residual volume	Capacity	Detrusor pressure rise	Detrusor contractions	Maximum voiding pressure	Peak flow rate	Ureteric reflux	Trabeculation	Diverticula
1	C	400	Unrecorded		Unable to void		—	+	—
2	500	800	Unrecorded		Unable to void		+	++	+
3	500	750	20	—	20	10	—	++	+
4	800	800	60	+	Unable to void		—	+	—
5	350	450	100	++	Unable to void		+	+	—
6	20	250	34	—	Straining	23	—	+	—
7	150	200	> 100	++	Unable to void		—	++	+
8	C	850	30	+	> 100	< 5	+	+	+
9	200	300	40	+	Unable to void		—	++	—
10	(C)20	600	48	—	Suprapubic pressure	< 5	—	++	—
11	C	250	50	+	Unable to void		—	+	—
12	70	125	60	+	60	Not recorded	—	++	—
13	(C)200	250	70	++	> 100	< 5	—	++	+

C = catheterised and uable to void
 (C) = catheterised but able to void
 Capacity and residual volume—ml
 Detrusor pressure rise and maximum voiding pressure—cm H₂O
 Peak flow rate—ml/sec
 Where several volumes were available for the same parameter, the mean has been recorded.

removed and the patient was tilted semi-upright and placed in the right oblique position. The majority of patients could not void in this position but bladder morphology and vesico-ureteric reflux were assessed, and, in those patients who could void, the residual volume was measured once more.

Pre-operative assessment also included an intravenous urogram and culture of several midstream or catheter specimens of urine.

Videocysto-urethrography with pressure and flow studies was repeated 6 months to 5 years after implantation of the sacral anterior root stimulator. The post-operative procedure was similar to the pre-operative except that all voidings were done by means of the implant, and voiding pressures could therefore be measured in all patients. The transmitter had been previously set, partly by trial and error, to stimulus parameters that gave a good flow.

In addition to videocysto-urethrography the patients' urinary residual volume was assessed post-operatively on several occasions using a non-catheter dye dilution technique (Cotran and Kass, 1958). The intravenous urogram was repeated at approximately 6 months and every 2 years thereafter and several midstream specimens of urine were sent for culture.

Results

The pre-operative urodynamic parameters are shown in Table II. Five of the patients had permanent indwelling catheters and of the rest only two patients (6 and 10, both female) had residuals less than 50 ml. Eight of the patients had markedly hypertonic bladders with end-filling detrusor pressures greater than 40 cm H₂O, and all but one of these, as well as one other, had marked uninhibited detrusor contractions during slower filling cystometry. Only six of the patients were able to void at will, (one by straining and the rest by suprapubic percussion), during the urodynamic assessment. Of these, four had marked detrusor sphincter dyssynergia (patients 3, 8, 12 and 13).

Pre-operative radiological screening revealed vesico-ureteric reflux in patients 2, 5 and 8. In the former two it was bilateral grade one reflux and in the latter there was grade 2 reflux on the left only. All 13 patients had coarsely trabeculated bladders and patients 2, 3, 7, 8 and 13 had one or more bladder diverticula.

The post-operative urodynamic data are shown in Table III. No patient required an indwelling catheter and the residual urine was 50 ml or less in all cases. Although cystometric capacity was not increased in all patients the functional capacity was improved. The changes in functional capacity are shown in Figure 1.

All patients were able to void using the stimulator. It was considered that a peak flow rate of 10 ml/sec or more and a maximum voiding pressure of 80 cm H₂O or less were acceptable. Patients 5 and 10 initially had a high voiding pressure (100 and 85 cm H₂O respectively) so the frequency of pulses within bursts produced by their stimulators was reduced, thus lowering the voiding pressures to 70 and 60 cm H₂O respectively but maintaining a good flow rate and acceptable residual volumes.

Each patient was radiologically screened throughout at least one implant-driven act of micturition. After applying the transmitter to the receiver stimulation was commenced in bursts. The first burst produced

TABLE III
Postoperative urodynamic data

Patient number	Months post-operative	Filling cystometry				Voiding		Screening		
		Residual volume	Capacity	Detrusor pressure rise	Detrusor contractions	Maximum voiding pressure	Peak flow rate	Ureteric reflux	Trabeculation	Diverticula
1	57	24	1000	10	—	55	34	—	+	—
2	46	37	450	18	—	22	20	+	(+)	—
3	46	36	900	14	—	56	20	—	++	(+)
4	31	15	600	30	—	75	> 10	—	+	—
5	28	40	450	60	+	100—70	20	—	—	—
6	23	3	500	10	—	35	30	—	(+)	—
7	29	50	550	40	—	56	36	—	++	+
8	16	27	1000	20	—	42	> 10	—	—	+
9	20	26	520	80	+	60	10	—	++	—
10	13	8	1000	26	—	85—60	> 10	—	—	—
11	12	37	350	50	+	60	Not recorded	—	+	—
12	7	10	500	38	+	82	30	—	—	—
13	4	5	480	42	+	42	35	—	+	+

(+) = present but less than previously.

Symbols otherwise as for Table II.

Where several values were available for the same parameter, the mean has been recorded.

an immediate rise in detrusor pressure and was accompanied by closure of the external urethral sphincter. As soon as the burst of electrical stimulation ceased the external sphincter relaxed and contrast medium flowed down the urethra into the flowmeter or bottle. The detrusor pressure meanwhile fell slowly until the next stimulation burst, when the cycle repeated (Fig. 2). In most cases the bladder could be emptied completely in this manner but it was noted that as the detrusor fatigued voiding became less efficient; in two patients (cases 7 and 11) it was necessary to stop stimulating when the volume of urine passed between each burst became very small, and to wait for 2 or 3 minutes before stimulating again in order to empty the bladder completely. The actual voiding cystometrograms for patients 1, 2, 5, 8 and 13 are shown in Figure 2. The flow rate recordings for patients 1, 10 and 13 are shown in Figure 3.

FIG. 1

Preoperative and postoperative functional bladder capacity compared for patients 1-13. Functional bladder capacity is defined as cystometric capacity minus residual volume. Patients catheterised because unable to void are counted as having no functional bladder capacity. Functional bladder capacity was increased in every case.

FIG. 2

Voiding cystometrograms. For each of these 5 patients, the upper trace (R) records the rectal pressure, the lower trace (V) the vesical pressure, and the middle trace (S) the subtracted pressure. In conventional cystometry the subtracted trace would represent the pressure exerted by the detrusor but in some of our patients the rectal pressure is not always a true measure of intra-abdominal pressure. Rectal contractions can be distinguished from reflex contractions of the abdominal wall (which sometimes occur) by their slower onset.

- (a) *Patient 1.* The detrusor contracts and relaxes rapidly in response to stimulation but the pressure does not fall to its pre-stimulation level until the detrusor fatigues towards the end of stimulation. Rectal contractions caused by stimulation can be seen in the rectal record.
- (b) *Patient 2.* This patient's nerve roots were damaged at the time of operation and had not fully recovered when he underwent postoperative urodynamic assessment. His detrusor pressure rise in response to stimulation is small and at this time his peak flow rate was only 5 ml/sec. His nerve roots have since recovered and he is able to void at 20 ml/sec using his implant.
- (c) *Patient 5.* Efficient implant-driven micturition. The detrusor pressure did not fall to its pre-micturition level until the bladder was empty. Rectal contractions are conspicuous.
- (d) *Patient 8.* Reflex abdominal contractions are seen in the rectal and vesical records. The voiding pressure is low.
- (e) *Patient 13.* Efficient implant driven micturition. The detrusor pressure falls nearly to baseline between bursts of stimulation and the bladder empties quickly and completely.

FIG. 3
Flow rates

- (a) *Patient 1.* In spite of a small urinary volume he manages to empty his bladder at a good flow rate. This patient had had two sphincterotomies, but his urinary stream stops completely during bursts of stimulation.
- (b) *Patient 10.* Women usually generate a higher flow rate than men due to the decreased outflow resistance; this is shown here. The flow was reduced but not completely cut off during bursts of stimulation.
- (c) *Patient 13.* The time interval between bursts is longer, and the flow stops two seconds before the next burst. This is demonstrated by the small flow recording at the beginning of each stimulus burst caused by emptying of the urethra by contraction of pelvic floor muscles.

Continence

Of the 13 patients assessed, nine are reliably continent at night. Of these, both of the women and three of the men (3, 5, 12) are also completely dry during the day. They are able to void at socially acceptable time intervals and do not wear urine-collecting devices. Patients 8 and 13 are continent day and night but choose to wear condoms when at work, because the lavatories near them at work do not have space for wheelchairs. Patient 4 is continent by night and nearly continent in the day. He wears condom and leg-bag for safety on days when he intends to go out, but not on days when he intends to stay at home. Patient 2 is continent at night but not during the day. To achieve continence at night he needs to stimulate the striated sphincter by a continuous train of weak pulses through his implant. Patients 1, 7, 9 and 11 (of whom 1, 7 and 9 have had previous bladder neck and/or urethral surgery) are not yet reliably continent.

RÉSUMÉ

On a évalué les modifications urodynamiques provoquées par les stimulations des racines des nerfs antérieurs du sacrum chez treize patients blessés de la moelle.

Ces onze hommes et deux femmes avaient des vessies peu ou pas continentes avec un résidu important avant les implantations.

Il a été fait une vidéo-cystographie avec études des pressions et de la miction avant les implantations et ces études ont été répétées une fois au moins six mois après l'implantation.

Dans tous les cas, le résidu post-mictionnel était inférieur à 50 ml et la capacité fonctionnelle de la vessie augmentait à un taux normal. Tous les patients pouvaient vider à volonté leur vessie lorsqu'ils faisaient fonctionner le stimulateur en rafales. Ainsi était obtenu un flux mictionnel interrompu, à pression normale et à vitesse d'écoulement acceptable. De plus une amélioration nette du reflux vésico-rénal et une diminution de la trabéculatation vésicale était notée après l'implantation du stimulateur. Chez ces malades avec stimulateurs, neuf étaient continents la nuit; huit étaient aussis continents le jour.

ZUSAMMENFASSUNG

Es wurden in 13 Patienten mit Wirbelsäulverletzungen die urodynamischen Veränderungen nach Implantierung von einem sakralen Vorderwurzelreizgerät untersucht. Die 11 männlichen und 2 weiblichen Patienten hatten nur wenig oder keine Kontrolle über die Blase und litten an erheblichem Residualblaseninhalt. Vor der Operation wurde eine Videozystourethrographie durchgeführt und eine weitere zwischen 6 Monaten und 5 Jahren nach der Operation.

Der Residualblaseninhalt war in allen Fällen zu weniger als 50 ml reduziert und die funktionelle Blasenkapazität zu normalen Werten erhöht. Alle Patienten konnten durch Aktivierung des Reizgerätes mit Gruppen von Pulsen willkürlich entleeren. Es wurde dabei ein unterbrochener Strom mit normalem Entleerungsdruck und Akzeptabler Geschwindigkeit produziert. Befunde über Harnleiterrückstrom und Trabekalblase waren nach der Implantierung deutlich verbessert.

Seit Verwendung des Reizgerätes bleiben 9 Patienten während der Nacht trocken. Acht Patienten bleiben auch untertags trocken.

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