

## CONTINUOUS MONITORING OF DETRUSOR PRESSURE IN PATIENTS WITH A REFLEX URINARY BLADDER AFTER SPINAL CORD INJURY

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**ABSTRACT.** In spinal cord injury, the detrusor pressure, as a parameter of urinary bladder dysfunction, is related to incontinence and renal complications. In order to determine the intraindividual variation of maximum pressure and duration of detrusor contractions, in patients with a spinal reflex bladder, the detrusor pressure was registered during 24 hours of physiological filling in 16 patients. Between the bladder contractions the detrusor pressure was low in all patients, indicating high bladder compliance. During contractions the maximum detrusor pressure and its duration varied both inter- and intraindividually. In individual patients, however, mean values during the initial 12 hours correlated with mean values during the final 12 hours. Thus, mean values of a series of contractions appear to be characteristic of each patient and useful in describing the voiding pressure in spinal reflex bladder.

*Key words:* manometry, neurogenic bladder, pressure, spinal cord injuries—complications, urodynamics.

In rehabilitation of patients with spinal cord injuries the neurogenic bladder is of great importance with regard both to incontinence and to renal complications (24).

Detrusor pressure is used as a parameter of bladder function, and a high pressure during filling or emptying is believed to be a risk factor. In patients with myelodysplasia and autonomous bladder the renal complications are more common when a high detrusor pressure is required for leakage (15). In patients with a traumatic spinal cord injury and a reflex bladder with detrusor-sphincter dyssynergia (2) there is suspicion of a relation between high detrusor pressure and renal complications (27). Thus a urodynamic evaluation might be helpful in the choice of initial treatment and follow-up programme. While the detrusor pressure exceeds approximately 40 cmH<sub>2</sub>O the function of the upper urinary tract is temporarily affected (3, 17). Thus amplitude and duration of the detrusor pressure

increase are interesting parameters. The procedure of measuring the detrusor pressure is, however, not yet standardized. The type and position of the catheters vary and the filling rate may be rapid or slow, mimicking physiological conditions. In patients with normal bladder function a single cystometry is believed to give representative information about the detrusor pressure (26). Whether this is also true in patients with a spinal reflex bladder is not obvious (22), and detrusor pressure will be dependent on a complex interplay between detrusor and sphincter reflex function (19).

Our aim was to study patients with a spinal reflex bladder in order to evaluate the following questions:

- Is the detrusor pressure always low during the filling phase, i.e. between bladder contractions and between intermittent catheterizations?
- Does one bladder contraction give representative information about the maximum detrusor pressure and its duration, in an individual patient?

### PATIENTS

Patients with a traumatic spinal cord lesion treated in our department of rehabilitation were investigated, using the following inclusion criteria: a period of more than six months should have elapsed after spinal cord injury; the patient should have a reflex bladder, according to Lapidès' classification (12), with neither sensation of bladder filling nor voluntary control of bladder on clinical examination and cystometry; urinary tract operations should not have been performed. 17 patients entered the study, but one of these had to be excluded because a catheter was accidentally withdrawn during registration. Thus data from 16 patients are reported.

#### *General patient data*

All patients were men with an age ranging from 20 to 50, and a median of 27. The post lesion time ranged from 7

Table I. Patient data

The levels of the spinal cord injuries are shown. Level of cord injury means that the function is normal down to the segmental level marked and the degree of functional loss below the level is indicated by the Frankel classification. In addition to spontaneous reflex emptying, each patient emptied the bladder regularly by tapping (Tap) or clean intermittent catheterization (CIC)

	Patient no.															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Level of cord injury	C6	C6	C6	C6	C6	T5	T6	T7	T8	T8	T8	T10	T12	T12	T12	L1
Frankel class	B	B	A	A	B	A	B	B	B	A	B	A	A	A	A	A
Emptying by	Tap	Tap	Tap	Tap	CIC	CIC	Tap	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC

months to 22 years, with a median of 2 years. None of the patients had pressure sores.

#### Neurological data

The level of the lesion and Frankel classification (8) of each patient are shown in Table I. Those with an incomplete spinal cord lesion had no motor function below the level of the lesion, thus classed as Frankel B, and a typical anterior cord syndrome with no sensation of pain, heat or cold below the level of the lesion (10). The bulbocavernosus reflex, the anal stretch reflex and the achilles tendon reflex were positive in all patients. The quadriceps reflex and the cremaster reflex were positive in all but one patient.

#### Urological data

11 patients performed clean intermittent self-catheterization and five patients emptied their bladders by tapping (Table I). In addition all patients had spontaneous leakage with varying frequency and all used condoms with urinary collecting devices. On intravenous pyelography and gamma camera renography ( $Tc^{99m}$ DTPA), within one month before or after the present study, no patient had dilatation of the upper urinary tracts and all had normal renal function with a clearance range from 92 to 148 ml/min. During the urodynamic study and during the preceding week no patient was on any medication with known or suspected effect on the function of the lower urinary tract (7). No patient had clinical symptoms of urinary tract infection when admitted one week before the study, but patients with bacteriuria before admission were treated with appropriate antibiotics during the week before the study. No intravesical calculus was observed on X-ray examinations performed three days before the urodynamic study.

## METHODS

In the morning before the urodynamic studies, the bowels were emptied in the way normally used by the patients and cystometry was done in order to demonstrate a reflex bladder. From about noon the detrusor pressure was monitored during 24 hours.

One prevesical and two intravesical teflon artery catheters with an inner diameter of 1.0 mm and outer diameter of 1.5 mm (Cuells 301) were inserted suprapubically. Each catheter was introduced via a flexible leader (21). One

intravesical catheter and the prevesical catheter were connected to pressure transducers (Siemens Elema 746-5) via 100 cm long pressure monitoring tubes (Bentley) and the catheters were filled with saline. To get good transmission of pressure from the prevesical space, 7 ml of normal saline was initially infused. In addition, 3 ml/h were infused through the prevesical catheter during registration. The transducers were placed at the same level as the upper edge of the symphysis pubis and connected to a pressure amplifier (Siemens Elema 863) and a multichannel recorder (Watanabe Linear Corder Mark VII). A paper velocity of 0.5 mm/s was used. The system was calibrated to a water column and to the air pressure. The system was also calibrated to the air pressure after 12 hours and at the end of the registration. The intravesical and prevesical pressures were recorded, and the detrusor pressure was obtained by electronic subtraction. The intravesical catheter not connected to a transducer was used for filling during the initial cystometry.

During the 24 hours of registration the bladder was emptied in the way normally used by the patient, i.e. by tapping or intermittent self-catheterization and spontaneous reflex contractions. The emptied volumes were measured. The patient was allowed to alternate between supine and sitting positions in bed. The duration of a detrusor contraction was defined as the time during which the detrusor pressure exceeded 20 cmH<sub>2</sub>O. In addition to this duration, the time in which the pressure exceeded 40 cmH<sub>2</sub>O, during each contraction, was measured. The detrusor pressure during the filling phase was defined as the pressure measured from two minutes after a detrusor contraction to one minute before the next contraction. These time limits were chosen to exclude small slopes of the phasic detrusor contraction curves. The maximum detrusor pressure during contraction was rounded to the nearest 10 cmH<sub>2</sub>O. Methods, definitions, and units conform to the standards proposed by the International Continence Society (11) except where specifically noted. Spearman's correlation coefficient ( $r_s$ ) was used for statistical analyses.

## RESULTS

No complications from the punctures or the catheters were observed. A sensitive indication of the function of the catheters was the pressure variation

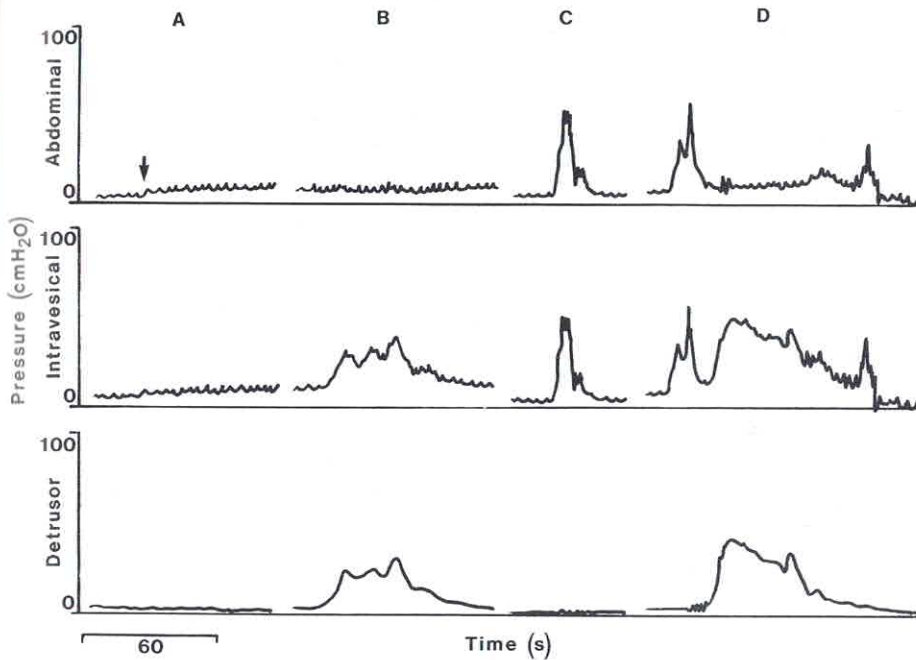


Fig. 1. The pressure curves. (A) The position of the patient is changed from supine to sitting, indicated by the arrow. Abdominal pressure rises but detrusor pressure is unchanged. The regular waves due to respiration are subtracted and not visible on the detrusor curve. (B) A detrusor contraction. (C) The patient moves in bed. Abdominal pressure is affected but detrusor pressure remains un-

changed. The same pattern was seen during involuntary spastic movements. (D) A movement with a rise of abdominal pressure followed by a detrusor contraction. The value of simultaneous registrations of intravesical and abdominal pressures with electronic subtraction is obvious.

due to respiration (Fig. 1). As indicated by Fig. 1 simultaneous recording of intravesical and abdominal pressure was important. There was no drift of the curves during the 24 hours. In the patients as a group the mean diuresis during 24 hours was 1.2 ml/min with a range of 0.7–1.8 ml/min.

#### The detrusor pressure

During the filling phase the increase of pressure was below 5 cmH<sub>2</sub>O and the final pressure was below 10 cmH<sub>2</sub>O in all patients. A total of 271 spontaneous reflex detrusor contractions was registered, and in all but two urinary leakage was noted. In all patients the detrusor pressure during contractions was characterized by a rapid rise and usually a plateau with one or a few peaks of short duration, and finally a slow decrease (Fig. 1).

The maximum detrusor pressure of the contractions is diagrammatically shown in Fig. 2. Most patients have a mode (most frequent) maximum pressure and some less frequent maximum detrusor

pressures distributed around that mode. The mean maximum detrusor pressure during the initial 12 hours correlated with the same measurement during the final 12 hours (Fig. 3).

The duration of the detrusor contractions varied from 10 sec to about 6 min, with considerable variation in each patient. The mean duration during the initial 12 hours, however, correlated with the same measurement during the final 12 hours;  $r_s=0.81$  ( $p<0.001$ ). The time in which the detrusor pressure was more than 40 cmH<sub>2</sub>O in each contraction, also varied considerably in most patients (Fig. 4). The mean time in which the detrusor pressure exceeded 40 cmH<sub>2</sub>O in contractions during the initial 12 hours correlated with the same measurement during the final 12 hours (Fig. 5).

In patients with high maximum detrusor pressures, the time in which the pressure exceeded 40 cmH<sub>2</sub>O tended to be longer than in patients with low maximum detrusor pressures (Fig. 6). There was a weak and not statistically significant correlation between the mean maximum detrusor pressure

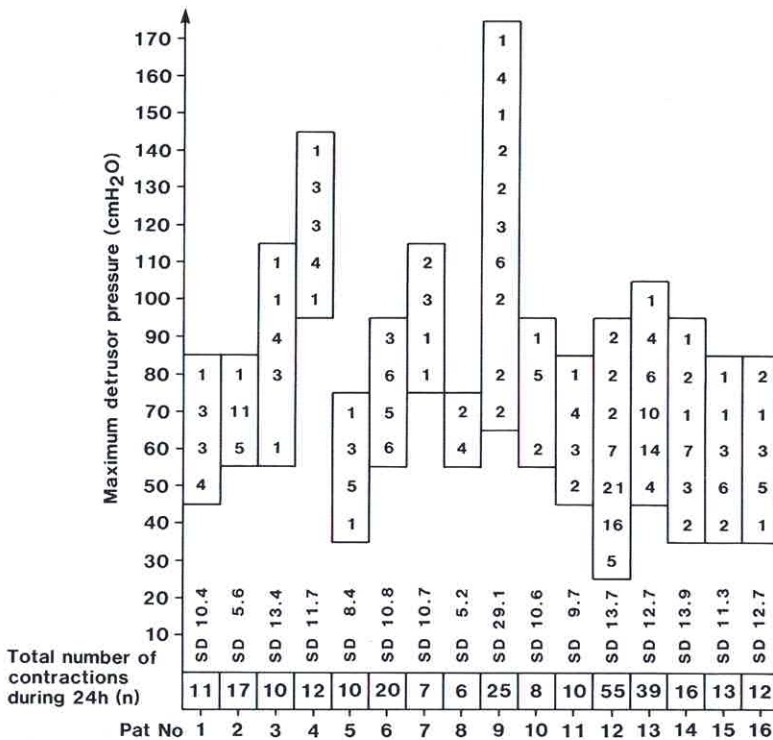


Fig. 2. The number of detrusor contractions with different maximum detrusor pressure in each patient during 24 hours. Contractions induced by tapping are not included. For each patient the standard deviation in cmH<sub>2</sub>O is given.

and the mean time in which the pressure exceeded 20 cmH<sub>2</sub>O (the mean duration).

## DISCUSSION

In this study of the detrusor pressure, we tried to minimize the risk of artefacts by using physiological filling (5, 14) and by avoiding catheters in the urethra (4, 9). Water filled catheters with external transducers were used (20) which gives a well defined reference level and a correct subtraction pressure. To get as close to the perivesical pressure as possible (1, 16) and to avoid pressure variations due to contractions of the rectum (13), we used prevesical catheters.

In neurogenic bladder dysfunction a high detrusor pressure of long duration may be present either during filling, if the compliance is low (15, 25), or during contraction, due to detrusor-sphincter dysynergia with prolonged emptying time and large residual volumes (2). It is still debatable what pressure amplitude or duration is acceptable in order to avoid renal damage (4, 18, 27).

The detrusor pressure during the filling phases was low in all patients, without physiologically significant variations. This tallies with the theory that

spared sacral reflex function is important in keeping the filling pressure low (15).

In no patient was the maximum detrusor emptying pressure constant during the registration. Al-

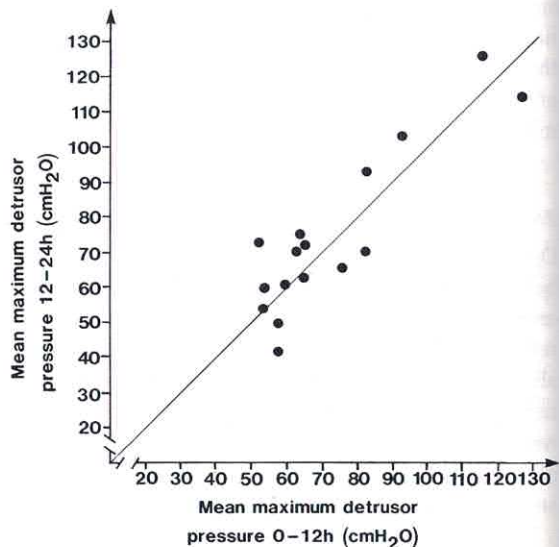


Fig. 3. The mean maximum detrusor pressure of each patient during the initial 12-hour period plotted against the final 12-hour period,  $r_s=0.72$  ( $p<0.001$ ).

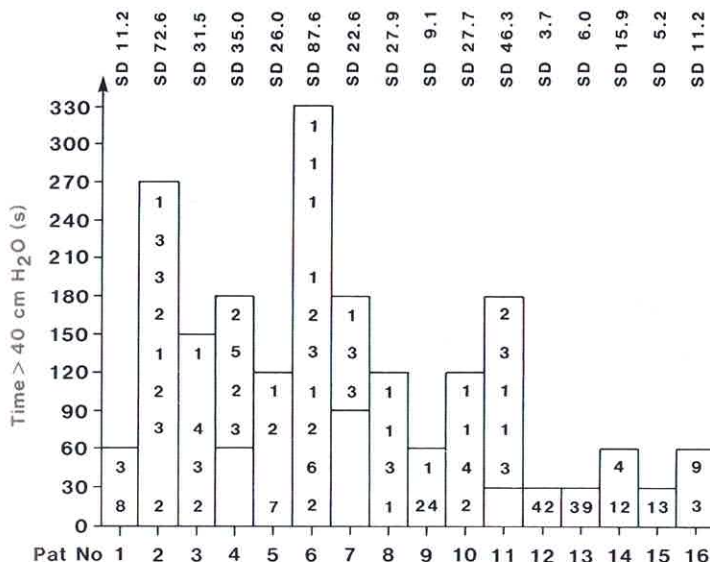


Fig. 4. The number of detrusor contractions exceeding 40 cmH<sub>2</sub>O and the time in which this level was exceeded. Since contractions not exceeding this level are not plotted, the total number of contractions are less than in Fig. 2 in some patients. Contractions induced by tapping are not included. For each patient the standard deviation in seconds is given.

though in many contractions the maximum pressure was close to the calculated mean maximum pressure of each patient, 14 patients had maximum pressures with an intraindividual range of at least 30 cmH<sub>2</sub>O (Fig. 2). In most of the patients there were maximum detrusor pressures both above and below 70 cmH<sub>2</sub>O which has been proposed as a limit (18, 27) for the risk of renal damage. This variation has to be considered when discussing whether the pressure of a patient is too high or not. Neither the duration of the contractions nor the time in which the pressure exceeded 40 cmH<sub>2</sub>O (Fig. 4) were constant in any patient.

However, a concept that the mean maximum pressure and the mean duration of the pressure rise in a number of contractions, obtained by repeated registrations during as physiological conditions as possible, are characteristic of each patient is supported by this study. The variation of the maximum detrusor pressure in each patient is reasonable if reflex sphincter and detrusor activity is the result of a number of interacting stimuli (14, 19), not modified by higher control functions (2). The parameters of the detrusor contractions of a patient may, like spasticity (6), be of a basic level depending on the lesion, but also vary depending on sensory stimuli. Despite avoiding major stimuli, such as urinary tract infection, some stimuli may be practically impossible to avoid during cystometry. In addition, some stimuli such as touch and proprioception are physiological and thus the cystometry would not

necessarily be more valid if all stimuli except bladder filling could be avoided. Within this concept urinary tract infections, bladder calculi, pressure sores and other complications may act as major sensory stimuli with effect on the reflex behaviour of the bladder.

If the mean maximum detrusor pressure and the mean duration of the rise of pressure in a certain

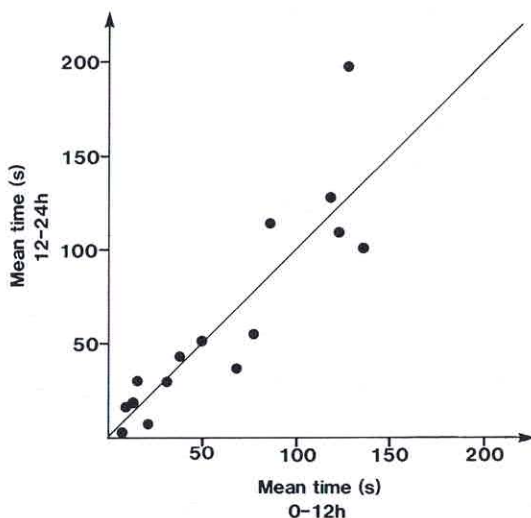


Fig. 5. The mean time of detrusor pressure exceeding 40 cmH<sub>2</sub>O in contractions during the initial 12-hour period plotted against the final 12-hour period,  $r_s=0.94$  ( $p<0.001$ ).

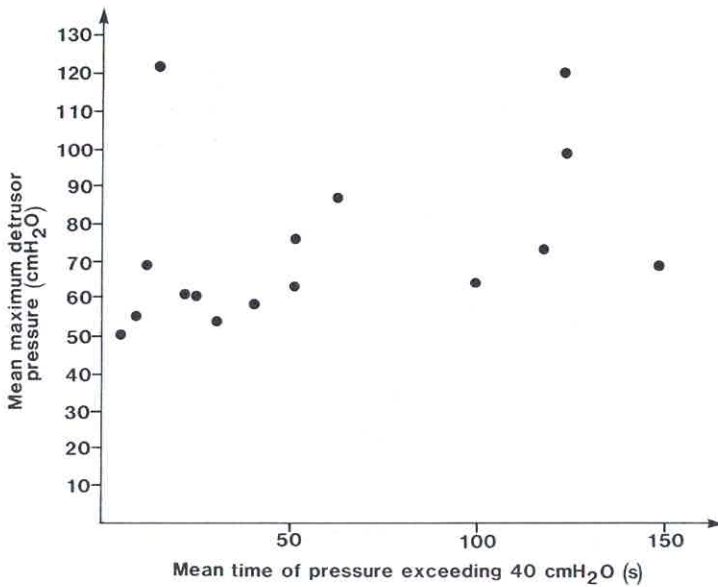


Fig. 6. The mean maximum detrusor pressure plotted against the mean time of pressure exceeding 40 cmH<sub>2</sub>O in each patient during 24 hours,  $r_s=0.53$  ( $p<0.025$ ).

number of emptying phases, during a period of physiological filling, are characteristic of each patient, these mean values would be useful in evaluation of pressure as a risk factor in spinal reflex bladder. Mean values from several contractions would also be useful in evaluation of different forms of therapy with possible effect on urinary bladder function. Regarding the maximum detrusor pressure, most patients had a standard deviation below 14 cmH<sub>2</sub>O. Thus, if the measurements had a normal distribution, registration of 8 contractions would with 95% probability give a mean pressure within 10 cmH<sub>2</sub>O from the patient's true mean maximum pressure. Registration of four contractions would with 95% probability give a mean pressure within 14 cmH<sub>2</sub>O from the true mean maximum pressure.

Regarding the mean time during which the detrusor pressure exceeded 40 cmH<sub>2</sub>O all but two patients had a standard deviation below 50 s. Thus, if the measurements had a normal distribution, registration of 8 contractions would with 95% probability give a mean time within 35 s from the true mean time. Registration of four contractions would with 95% probability give a mean time within 50 s from the true mean time.

In the individual patient the need for precision will depend on how exactly the risk levels can be defined and how close to these levels the patient's mean values are. If these mean values could be predicted by a few registrations of standardized

retrograde filling cystometry the evaluation would be easier in clinical practice. The possible influence of non physiological filling rates (5) requires further study.

In addition to detrusor pressure, reflux and residual urine with infection are considered to be risk factors. These factors are thought to interact but the exact role of each factor in the presence or absence of the others is not fully understood (4, 23). Regarding the detrusor pressure, a rise to about 40 cmH<sub>2</sub>O of long duration may affect the upper urinary tract even if reflux is not present (3, 17). Richter et al. (18) found a correlation between maximum detrusor pressure and pressure time in patients with a spinal reflex bladder. We found a weak and not statistically significant correlation. However, a moderate correlation between maximum detrusor pressure and the time in which the pressure exceeded 40 cmH<sub>2</sub>O was found in our study. Richter et al. also found that reflux only developed in patients with a maximum detrusor pressure above 70 cmH<sub>2</sub>O and a pressure time above 60 s. Further research should also consider the indications and the therapeutic value of sphincterotomy, clean intermittent self-catheterization and anticholinergic drugs. In rehabilitation of patients with spinal cord injuries these questions have to be discussed with respect to 1) risk factors and their relation to renal damage and 2) continence and its relation to the quality of life.

## CONCLUSION

In patients with a spinal reflex bladder the detrusor pressure during physiological filling is low in the absence of phasic contractions, i.e. bladder compliance is high. No clinically significant variation is obtained in repeated filling.

With physiological filling the intraindividual variation of the maximum detrusor pressure and its duration, during contraction, makes it necessary to use mean values from several contractions in studies of these parameters in a patient.

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