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Obstructive effect of a closed 12F urethral catheter during the emptying phase of cystometry in patients with a spinal reflex bladder

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In spinal cord injured patients with a reflex urinary bladder urodynamic evaluation of the detrusor pressure during the emptying phase is important, but the methods are not yet standardised. The aim of this study was to examine whether the detrusor pressure is significantly affected by the presence of a catheter in the urethra. In seven patients with a spinal reflex bladder, the maximum detrusor pressure and the duration of detrusor contractions in cystometry with a suprapubic technique were compared with the corresponding measurements when a closed 12F catheter was added to mimic a transurethral cystometric technique. Four cystometries were performed with about 10 min intervals and the mean values from two cystometries without the urethral catheter were compared with the mean values from two cystometries with the catheter. After addition of the urethral catheter there was an increase of the mean maximum detrusor pressure form 8.4 to 10.5 kPa ($P = 0.009$). The mean duration of the detrusor contraction increased from 122 to 191 s ($P = 0.031$) and the mean time during which the detrusor pressure exceeded 4 kPa, in each contraction, increased from 60 to 150 s ($P = 0.009$). The average flow rate, calculated as the voided volume divided by the duration of a contraction, decreased from 1.4 to 0.6 ml s^{-1} ($P = 0.009$). Because of the observed obstructive effect, cystometric evaluation of the detrusor pressure during the emptying phase with a urethral 12F, or larger, catheter will in patients with a spinal reflex bladder, with a high probability, give a detrusor pressure of a higher amplitude and longer duration and a lower flow rate compared with the normal daily pathophysiological conditions, or cystometries with a suprapubic technique. This might not be a severe problem if for example some kind of therapeutic procedure is evaluated with the same technique before and after treatment. However, when comparing results of different types of studies, or in general discussions about pathophysiological mechanisms and risk levels, the observed difference has to be considered.

Keywords: manometry; neuropathic bladder; spinal cord injuries; urodynamics

Introduction

In spinal cord injured patients there are at least two important consequences of the impaired function of the urinary bladder: incontinence and the risk of upper urinary tract dysfunction. Upper urinary tract dysfunction means the development of either hydronephrosis, vesicoureteral reflux, chronic pyelonephritis or a reduced creatinine clearance.[1,2] In patients with a spinal injury the most common type of neuropathic bladder is the spinal reflex bladder.[3] If there is severe detrusor–sphincter dyssynergia there may be prolonged detrusor contractions during emptying of the bladder, or during attempts to empty against a contracted sphincter. If the residual urine is large, in relation to bladder capacity, the periods with elevated detrusor pressure may be frequent.

When the detrusor pressure exceeds approximately 4 kPa the function of the upper urinary tract is temporarily affected, also in the absence of reflux. In adults with normal urinary tract function, Pierce and Braun[4] found that the efflux of urine from the ureter ceased at intravesical pressures of about 4 to 5 kPa. When Shalit and Morales[5] examined nine patients with normal function and 12 with a reflex bladder, caused by a spinal cord injury, they found an increased ureteral pressure when there was an increase of intravesical pressure at the end of bladder filling and the start of bladder contraction. Similar results were obtained by Zimskind *et al.*[6] In patients with various neurological lesions, Butler *et al*[7] found ureteral dilatation and diminished peristalsis when the intravesical pressure was about 5 kPa.

The methods that are used to protect the function of the upper urinary tracts, for example intermittent catheterisation, pharmacological treatment or sphincterotomy, can be chosen only after the patient has been evaluated regarding urodynamic characteristics. In patients with a spinal reflex bladder the detrusor pressure during voiding is an important variable.[2,8] In some patients with severe dyssynergia there may be

both a high amplitude of the detrusor pressure and a long duration of the contractions.[9] However, most urodynamic studies have not been focused on the duration of the detrusor contractions, and its relation to the amplitude has not been clarified.[10–12] A maximum detrusor pressure of around 7 kPa has been suggested as an upper limit for renal damage.[1,2,8,9,13,14] If the maximal detrusor pressure is below that level, balanced voiding may be said to exist, provided there is also an acceptable compliance and a low residual urine. In a study of 100 patients with spinal cord injury and a hyperreflexogenic bladder Gerridzen *et al*,[2] on excretory urography, found hydronephroses in 16%. These patients had a mean maximum detrusor pressure of 11.5 kPa, while those with normal urinary tracts had a mean maximum detrusor pressure of 7 kPa. The urodynamic investigation was done with a combination of a transurethral 8F (filling) and 4F (pressure) catheter and a rectal balloon.

In repeated cystometries there may be maximum detrusor pressures both above and below 7 kPa in the same patient. The duration of contractions and the time during which the pressure exceeds 4 kPa may also vary intraindividually.[10,11] This variation has to be considered when discussing whether or not the pressure of a patient is too high. In addition, the cystometric method that is used to evaluate the detrusor pressure during the emptying phase may influence the result. If a urethral catheter with an abnormally large diameter is used, urinary flow will be obstructed. The degree of obstruction is difficult to predict because it is difficult to know whether the urethra will relax or contract and how the musculature and mucosa will adapt to the catheter. Furthermore it is not certain that the spinal detrusor reflex will react in the same way if there is voiding through a urethra that is only functionally obstructed, perhaps intermittently, by a dyssynergic sphincter, or if the voiding occurs around a catheter that partially obstructs the urethra, or if it is totally obstructed by a large catheter, producing a pure isovolumetric contraction.

The aim of this study was to evaluate whether there is a clinically significant difference between the detrusor pressure measured by a 12F urethral catheter compared with a suprapubic technique.

Patients

As a part of the routine urodynamic assessment programme, seven patients entered the study. According to the inclusion criteria the patients should have a spinal cord injury with a spinal reflex urinary bladder, according to the Lapides's classification,[3] with reflex voiding and neither sensation for bladder filling nor voluntary control of the bladder according to clinical observations and cystometry.

All patients were male with ages ranging from 20 to 51, and a mean of 26 years. All had a traumatic spinal cord injury. The neurological functional level and the Frankel classification[15] of each patient is given in Table 1. Those classified as Frankel B had an anterior cord syndrome with no voluntary motor function and no sensation for pain or temperature below the functional level. The cremaster-, quadriceps-, achilles-, bulbocavernosus- and anal stretch reflexes were positive in all of the patients. The mean time since the onset of the lesion was 6 years, with a range from 6 months to 18 years.

Table 1 Neurological functional level and classification according to Frankel

	Patients						
	1	*2*	*3*	*4*	*5*	*6*	*7*
Level	T7	T4	C5	C5	C6	C6	T8
Frankel grade	A	B	A	B	A	B	A

None of the patients had any known additional disease or anatomical obstruction of the urethra. No patient had intravesical calculi or symptomatic urinary tract infections at the time of the study. Five patients with bacteriuria were treated with appropriate antibiotics during the week before the study. No patient had pressure sores or other suspected additional stimuli below the level of the lesion. The bowel was emptied in the morning before the study. No patient was on any medication with known or suspected effect on urinary tract function.

Methods

In four cystometries with suprapubic catheters, a closed 12F urethral catheter was added during the third and fourth cystometry to mimic a transurethral technique. In this study, one cystometry is defined as measurement of the detrusor pressure during both the filling and the following emptying phase. The cystometries were performed with 37 °C normal saline and a filling rate of 50 ml min^{-1}. Filling was stopped as soon as a detrusor contraction was observed and the detrusor pressure exceeded 2 kPa. No suprapubic tapping or other additional stimulation, except bladder filling, was performed during the cystometries. After the detrusor contraction had ceased the voided volume was measured. The residual volume was emptied through the catheters and measured after each cystometry. The interval between the end of one cystometry and the start of the next was about 10 min. The patients were in a bed with the upper part of the body elevated 30°.

Two intravesical and one prevesical Teflon catheters, with an outer diameter of 1.5 mm and an inner diameter of 1.0 mm (Cuells 301, Cuells Mediprodukter, Huddinge, Sweden), were introduced suprapubically after skin anaesthesia with lidocaine. One intravesical and the prevesical catheter were connected to pressure transducers (Abbot Transpac II, Abbot Scandinavia, Kista, Sweden). 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, Siemens Elema, Sundbyberg, Sweden) and a multichannel recorder (Watanabe Linear Corder Mark VII,

Kaliber, Vallingby, Sweden). Paper velocity was $1\,mm\,s^{-1}$. The system was calibrated against a water column and air pressure. The pressure measurement catheters were perfused at a rate of $30\,ml\,h^{-1}$ and low-compliant measurement systems were used.[16] The detrusor pressure was obtained as the difference between the intravesical the prevesical pressures by electronic subtraction. The urinary bladder was filled through the second intravesical catheter.

After the first two cystometries, a closed 12F Nelaton catheter (Althin Mediplast AB, Taby, Sweden) was introduced via the urethra. It was fixed to the penis with adhesive tape. The voided volume that was emptied around the catheter was collected in a bottle in the same way during all four cystometries.

At each cystometry the maximum detrusor pressure and the duration of the detrusor contraction were measured. The start of a detrusor contraction was defined as the time at which the detrusor pressure exceeded 2 kPa and the end of a contraction was defined as the time at which the pressure returned below 2 kPa, in a phasic contraction. The time during which the pressure exceeded 4 kPa, in a contraction, was also measured. The average flow rate was defined as the voided volume divided by the duration of the contraction. The bladder capacity was defined as the filled volume at which a detrusor contraction occurred, ie when the detrusor pressure exceeded 2 kPa and the filling was stopped.

Wilcoxon's signed rank test was used to test differences and $P < 0.05$ was regarded as significant.

Results

Both the amplitude and the duration of detrusor pressure elevation increased significantly after the addition of the urethral catheter (Table 2). In each patient there was an increase of the mean (mean of two cystometries) maximum detrusor pressure. In the group, the mean maximum detrusor pressure increased from 8.4 kPa (range 5.5–14.8, SD 3.0) to 10.5 kPa (range 8.0–17.2, SD 3.3). The mean duration of the detrusor contraction increased in all but one patient. In the group the duration increased from 122 s (range 25–302, SD 100) to 191 s (range 32–467, SD 157). The mean time during which the detrusor pressure exceeded 4 kPa, in a contraction, increased in each patient. In the group, this variable increased from 60 s (range 16–129, SD 49) to 150 s (range 30–414, SD 135).

After the addition of the urethral catheter the average flow rate, calculated as the voided volume divided by the duration of the contraction, decreased significantly (Table 2). In all patients the voided volumes, during the reflex bladder contraction, were small without the urethral catheter (mean 89 ml, range 40–130) and became even smaller when the patients voided around the catheter (mean 54 ml, range 10–130). The mean (mean of two cystometries) calculated average flow rate decreased from $1.4\,ml\,s^{-1}$ (range 0.2–3.8, SD 1.4) to $0.6\,ml\,s^{-1}$ (range 0.04–1.4, SD 0.5). All patients were considered to have signs of detrusor–sphincter dyssynergia since the observed urine flow was low during each detrusor contraction.

In six of the seven patients, there was a decrease of the bladder capacity after addition of the urethral catheter (Table 2). However, in the group this decrease was not statistically significant.

Regarding each variable, there was no significant difference between the two cystometries with only suprapubic catheters nor between the two cystometries with a urethral catheter.

Discussion

The increase of the amplitude and duration of detrusor pressure and the decrease of the mean flow rate that was observed indicates a significant obstructive effect of the urethral 12F catheter. Especially in patients with a spinal reflex bladder and detrusor–sphincter dyssynergia, the degree of obstruction would be difficult to calculate theoretically, because both distension and contraction of the urethra are possible events during the micturition.

In 10 women (five healthy and five with obstructed bladder outlet), Hopkins *et al*[17] compared measurements with a transurethral 5F catheter with the suprapubic way. They found a decrease of urinary flow with a catheter in the urethra but no difference with regard to intravesical pressure during micturition. Backman *et al*[8] found no difference in urinary flow or detrusor pressure when they compared measurements by a suprapubic catheter with a 5F urethral catheter in four healthy women. When Gierup *et al*[19] studied the effect of a urethral 5F catheter, in 17 small boys with various diagnoses, they found a decrease of maximum flow rate but no change in intravesical pressure measured by a suprapubic catheter. Hanna *et al*[20] observed an increased urinary flow rate, in 10 children with various symptoms, with no catheter in the urethra compared to an 8F catheter. Neal *et al*[21] found that a 3F catheter in the urethra compared with a combination of a 10F and 4F catheter gave a reduced detrusor pressure (from 8 kPa to 7 kPa) at maximum flow in 20 men with obstruction but there was no difference in 10 men without obstruction after prostatectomy. A detailed comparison of the studies is difficult because of differences in patients, methods and presentation of results.

In our group, the patients may be supposed to have a functional obstruction of varying degree because of detrusor–sphincter dyssynergia. The difference regarding the maximum detrusor pressure seems to correspond with the difference that Neal *et al*[21] found in their patients with anatomical obstructions. They used a combination of a 10F and a 4F catheter. It may be difficult to predict the effect of a combination of, for example, two 10F catheters, ie whether the space between the two catheters may be sufficient to give a significant decrease of the outlet resistance in patients with a hyperactive sphincter. If a single catheter is used, a size of 12F or larger, it will with a high

Table 2 Data regarding maximum detrusor pressure, duration of contraction, time during which the pressure exceeded 4 kPa in a contraction, average flow rate and bladder capacity

	Patients							*Mean*	*P*
	1	*2*	*3*	*4*	*5*	*6*	*7*		
Detrusor pressure (kPa)									
Without catheter	7.0	14.75	8.75	7.25	5.5	6.75	8.75	8.4	0.009
With catheter	10.5	17.25	11.5	8.0	8.0	8.5	9.5	10.5	
Duration (s)									
Without catheter	25	167	55	302	182	73	49	122	0.031
With catheter	32	154	60	467	283	265	76	191	
Duration above 4 kPa (s)									
Without catheter	16	123	36	129	73	16	30	60	0.009
With catheter	30	131	47	414	206	173	50	150	
Bladder capacity (ml)									
Without catheter	145	175	330	280	400	190	260	254	0.088
With catheter	125	125	275	250	300	255	230	223	(NS)
Voided volume (ml)									
Without catheter	71	55	85	130	70	40	170	89	0.064
With catheter	42	40	65	35	10	130	55	54	(NS)
Average flow rate (ml/s)									
Without catheter	2.84	0.33	1.58	0.24	0.39	0.56	3.79	1.4	0.009
With catheter	1.35	0.25	1.11	0.08	0.04	0.47	0.74	0.6	

Each figure, in a patient, represents the mean of two observed values (two cystometries without and two cystometries with a closed 12F catheter in the urethra). Regarding each variable, the right column gives the significance (*P*) of the difference, as calculated with Wilcoxon's signed rank test (NS = not significant at 0.05 level).

probability give some artefacts regarding the detrusor pressure and the flow rate. Further studies may show how small the diameters should be of urethral catheters that have to be used in order to obtain values comparable to the normal daily pathophysiological conditions of patients with a reflex bladder.

In this study there was a small but not statistically significant difference in the bladder capacity after introduction of the catheter. It is possible that the introduction of a urethral catheter may affect detrusor function by stimulation of spinal reflexes. Von Garrelts[22] reported that the transurethral introduction of a 5F catheter was associated with a feeling of discomfort until it was fixed in position. During micturition, a burning sensation was reported. In experimental touching of the posterior bladder neck with a 10F catheter in spinal cord injured patients with detrusor hyperreflexia, bladder contractions and voiding were induced by Perkash and Wolfe.[23] Stimulation of the bladder wall or other areas of the urethra did not give this reaction.

In consecutive cystometries, one may question whether the detrusor reaction is affected by the mere repetition of the procedure, especially if there is too short an interval between cystometries or an overdistension by filling against a contracted bladder with a blocked urethra. Although most studies of reproducibility in consecutive cystometries have focused on bladder capacity, without taking into consideration measurement of detrusor pressure during the contraction, there still exist different opinions as to whether the capacity is systematically affected by the repetition of cystometry. Sörensen *et al*[24] reported an increase while Nordling and Walter[25] observed a decrease and several authors[26–28] found no systematic change of the bladder capacity. Regarding the maximum amplitude of the detrusor contraction, no systematic change was observed in detrusor hyperreflexia by Grynderup[29] in double cystometries performed in patients with multiple sclerosis nor by Petersen and Hedegaard[30] in three or four cystometries performed in patients with various neurological lesions. Grynderup used a urethral 18F two-way Foley catheter and a filling rate of 50 ml min^{-1} which was interrupted when a reflex contraction occurred, except in specific studies of the effect from distension above this capacity. In the studies of Grynderup[29] a distension above the capacity at which the first contraction occurred resulted in an increased capacity during repetition of the cystometry after a 5-minute interval but the maximum contraction pressure was not systematically changed. When Shoukry and Ghoniem[31] studied the effect of time interval and overdistension in a series of experiments on five *Macacae mulattae*, they found that capacity, compliance and detrusor strengh were reproducible urodynamic variables after a 30-minute interval. In the case of overdistension, with 120% of capacity, a 45-minute interval was required. Like Grynderup,[29] they used a catheter that blocked the outflow, thus measuring the isovolumetric detrusor pressure at contraction. In patients with an uninhibited neuropathic bladder and various neurological diseases, Jensen[32] studied the influence of repeated filling and varying the filling rate. Regarding some variables, such as the

amplitude of the uninhibited detrusor contraction, the interpretation of the study is somewhat complicated because different methods were used in some patients. Bladder filling and measurement of intravesical pressure were performed with a transurethral 3-way 18F Foley catheter. In most of the examinations, the infusion rate was 50 ml min^{-1} and infusion was usually interrupted when there seemed to be a peak contraction. When the cystometry was repeated immediately in 17 patients, the mean amplitude of the uninhibited contraction was reduced significantly from about 11 to 9 kPa. From the data about filling rate and capacity, in addition to the estimated time for withdrawal of residual urine, the interval between the cystometries seems to have been about 3 min. Again, a comparison of studies is difficult because of the differences in patients and methods. We have not seen any systematic change of the detrusor pressure during a series of four consecutive cystometries, with 10-minute intervals, in patients with a spinal reflex bladder when the filling was stopped as soon as a contraction was observed,[33] as in the present study, nor when the filling was stopped as soon as micturition was observed.[11] Furthermore, the presently observed difference regarding the detrusor pressure, without and with a urethral catheter, was in the opposite direction compared with the possible decrease that was observed by some authors during repetitive cystometries. In further studies, however, a randomisation of the sequence would improve the method.

Conclusions

Because of the observed obstructive effect, cystometric evaluation of the detrusor pressure during the emptying phase with a urethral 12F or larger catheter will in patients with a spinal reflex bladder, with a high probability, give a detrusor pressure with a higher amplitude and longer duration and a lower flow rate compared with the normal daily pathophysiological conditions. The magnitude of the observed differences and the high statistical significance in this small group of patients implies that the difference between the studied methods is clinically significant. This might not be a serious problem if for example some kind of therapeutic procedure is evaluated with the same technique before and after treatment. However, with comparisons of the results from different types of studies, or in general discussions about pathophysiological mechanisms and risk levels, the observed difference has to be considered.

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