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Urethral Closure Pressure with Stress – A Comparison Between Stress-Incontinent and Continent Women

G. Bunne and A. Öbrink

Department of Obstetrics and Gynaecology, Karolinska Institute, Sabbatsbergs Hospital, Stockholm, Sweden

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Summary. Stress incontinence has been said to occur as a consequence of a low urethral pressure and defective pressure transmission from the abdomen to the urethra due to descent of the bladder neck area. Equipment suitable for dynamic pressure measurements has been used to analyse the losses of urethral pressure that lead to incontinence. The pressure transmission from abdomen to urethra was found to be incomplete in both continent and stress-incontinent women. There was also significant loss of smooth muscle tone in the urethral wall after repeated straining, leading to a still narrower margin between the urethral pressure and the leakage treshold in both continent and stress-incontinent women. The main factor determining the degree of continence or incontinence seemed to be the urethral closure pressure at rest. As long as this pressure is sufficiently high, leakage during sudden stress will not occur.

Key words: Urinary stress incontinence - Urodynamics.

No convincing and generally accepted theory has yet been presented concerning the genesis of stress incontinence. The mechanism of incontinence with sudden stress is obscure, but some clues have resulted from synchronous urethrocystometry. By drawing a pressure-receptor through the urethra at constant velocity the urethral pressure profile is recorded. The part of the urethra where the pressure exceeds the bladder pressure is called the functional urethra. The positive closure pressure (urethral pressure minus bladder pressure) maintained here prevents leakage at rest (4).

The stress-incontinent condition is associated with a considerably shortened functional urethra and an impaired urethral pressure, probably as a consequence of damage to the urethral supporting tissue (4, 7).

In 1961 Enhörning presented the theory that stress incontinence is characterised by defective transmission of pressure from abdomen to urethra, leading to leakage mainly for hydrodynamic reasons (4). The theory of a defective pressure transmission has been neither contradicted nor further verified because of lack of suitable investigative methods.

Simultaneous urethrocystometry can nowadays be performed with high precision, using microtransducers (strain gauge principle) (2, 3).

These are enclosed in a thin and semi-flexible catheter which is suitable for dynamic investigations. This paper reports studies of the changes in urethral closure pressure and the pressure transmission during stress. The records have been obtained during repeated coughs of different strengths, allowing a detailed analysis of the decrease in closure pressure.

PATIENTS

Groups of stress incontinent and completely continent women have been compared.

The stress-incontinent group consisted of 11 women with genuine stress incontinence of second degree on the Ingelman-Sundberg scale (5); mean age 58 years (range 43-69), mean

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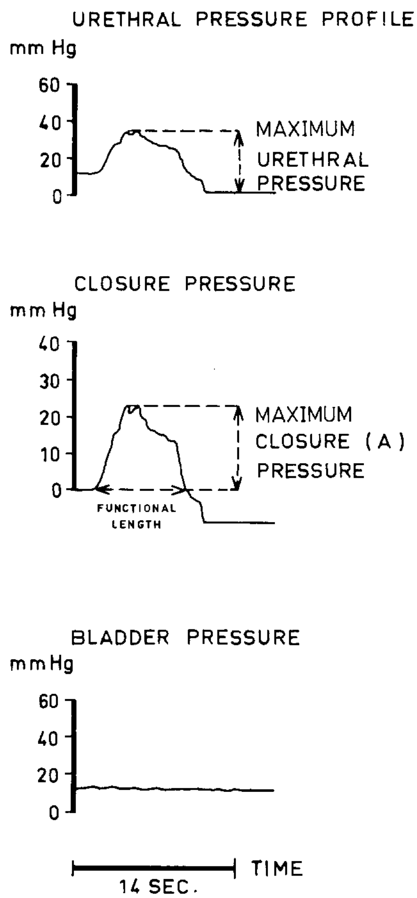

Fig. 1. The three simultaneously recorded parameters

parity 1.9 (range 1-3). None of the patients had previously undergone either abdominal or vaginal gynaecological surgery. All of them had a marked descent of the anterior vaginal wall, including the bladder neck area, accentuated on coughing, and a Bonney positive urinary leakage could be provoked. No urinary infection was present at the examination. Three women were on an oral oestrogen regimen.

The continent women were selected from women hospitalised because of postmenopausal bleeding. The group had a mean age of 52 years (range 42-59) and a mean parity of 2.2 (range 1-4). The basic criterion was total continence, i.e. no involuntary leakage whatsoever, not even in a situation of extreme stress in the erect position. This group does not represent the normal situation, since most women of this age experience leakage at some time during life. More than 50 % of the women asked to participate had experienced this low-degree of stress incontinence and were excluded. The gynaecological findings in this group were otherwise normal and they did not have any urological disorder. None of them were receiving oestrogens or other medicine. The women were informed of the aims of the investigation and gave their consent to participation.

METHODS

The equipment for recording the pressure in urethra and bladder simultaneously has been described earlier by Asmussen and Ulmsten (2, 3) and reproducibility and precision of results are good even at high frequencies and amplitudes. It consists of a thin (diam. 2.34 mm) semiflexible Dacron catheter with two micro-transducers, one at the tip of the catheter and the other 60 mm proximally, three amplifiers and a recorder. Electronic subtraction was used to obtain a record of the urethral closure pressure. To record the urethral pressure profile, the catheter was mechanically withdrawn through the urethra at a velocity of 2.5 mm/s.

Experimental Procedure

The patient was placed in the lithotomy position. Residual urinary volume was estimated and the bladder was filled with 100 ml 0.9 % saline solution. The catheter was inserted into the bladder transurethrally, both micro-transducers being in the bladder. Three consecutive urethral pressure profiles were recorded at rest (Fig. 1) and the third one was used for subsequent calculations (6). Thereafter the patient was asked to cough repeatedly (approx. once per second) with constant force while the profile was recorded. Such profiles were repeated with coughs of different strength, corresponding to bladder pressure increments of approximately 15, 30, 50 and 70 mmHg (Fig. 2). The catheter was adapted to the urethral slope before attaching it to the withdrawal apparatus, and all measurements were made with the sensor areas of the catheter directed laterally to avoid artifacts. Some profiles with artifacts were difficult to interpret and the "cough profiles" were therefore supplemented by another method of recording the coughs so as to be able to estimate the degree of transmission. This method involved holding the catheter manually at the external urethral meatus so that the proximal sensor area lay at the point of highest urethral pressure while the patient coughed repeatedly.

The whole procedure was repeated at a bladder volume of 300 ml. The patients were asked to try not to "hold urine" actively during coughing.

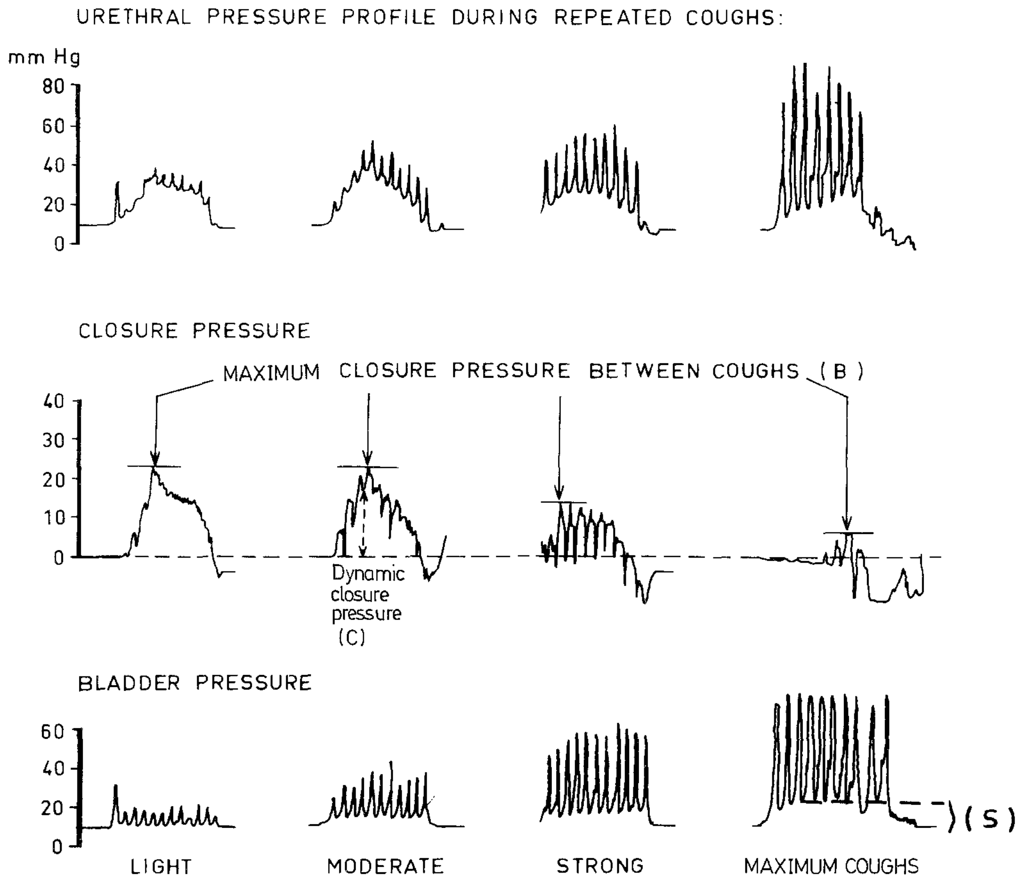

Fig. 2. The same parameters as in Figure 1 during repeated coughs in a stress-incontinent woman who leaked at strong coughs

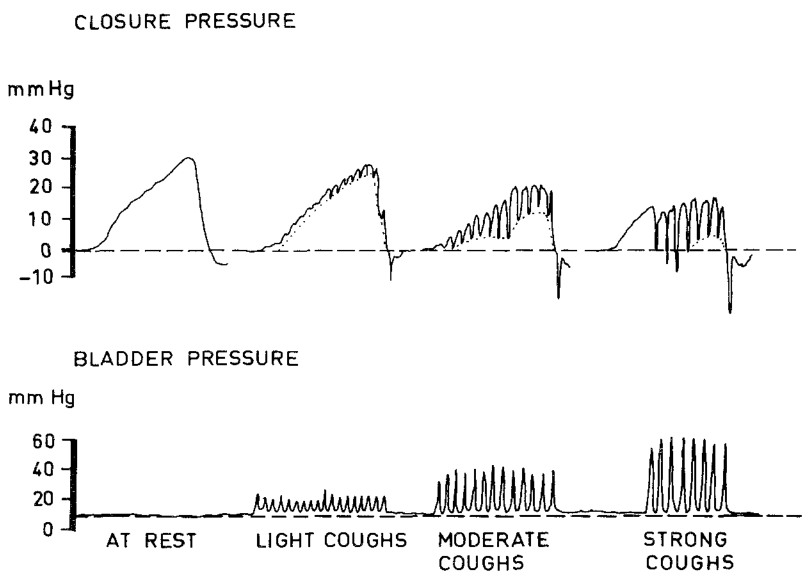

Fig. 3. Urethral closure pressure during coughs of increasing strength in a continent woman. Note the decreasing margin above the leakage threshold (the area under the dotted curve)

Table 1. Urethral Values at Rest (mmHg)

	Continent (n = 10)		Stress incontinent (n = 11)	
Bladder content (ml)	100	300	100	300
Functional length (mm)	31.3	32.1*	26.2	24.0*
	(5.68)	(6.01)	(3.40)	(5.15)
Maximum closure pressure (mmHg)	44.4*	41.2*	21.2*	20.9*
	(15.21)	(17.63)	(3.57)	(5.07)
Bladder pressure (mmHg)	7.4	8.4	10.7	11.0
	(1.84)	(1.84)	(3.26)	(2.57)

The data are mean values, followed by the standard deviation in parenthesis. Statistically significant differences ($p \leq 0.01$) between continent and stress incontinent groups are indicated*

Definitions (Figs. 1 and 2)

Urethral Pressure: The pressure within the urethra in relation to atmospheric pressure.

Intravesical Pressure: The pressure within the bladder in relation to atmospheric pressure.

Urethral Pressure Profile: Continuous recording of the intraluminal pressure throughout the entire length of the urethra.

Urethral Maximum Closure Pressure: The maximum intraurethral pressure minus the bladder pressure (at rest = A).

Functional Length of the Urethra: The part of the urethra where the intraluminal pressure exceeds the bladder pressure.

B = urethral maximum closure pressure immediately after repeated coughs.

C = dynamic urethral maximum closure pressure (at the moment of a cough).

A-B signifies the loss of urethral closure pressure immediately after repeated coughs.

B-C signifies the defect in pressure transmission to urethra at a cough. (The bladder pressure being assumed to reflect the intra-abdominal pressure.)

A-C = the total loss of urethral closure pressure at the moment of cough.

S = the degree of straining (mmHg) calculated from the bladder pressure curve at the time of maximum dynamic closure pressure.

RESULTS

The changes in urethral closure pressures during coughs of increasing intensity are shown in Figure 3. Urethral closure pressure and bladder pressure were recorded during an ordinary urethral pressure profile at rest and three "cough profiles" were obtained. The areas under the dotted curve represent the positive closure pressures remaining during coughs of a certain strength. This areas diminished the harder the patients coughed. However, as long as closure pressure remained positive in any part of the urethra, leakage did not occur.

Two factors contributed to the reduction of closure pressure in the dynamic situation:

1. During a series of frequent coughs closure pressure did not return to the value at rest between the coughs. The closure pressure curve became flatter the stronger the patients coughed.

2. A cough caused an instant fall in closure pressure because bladder pressure increased more than urethral pressure. This means that the rise in intra-abdominal pressure is transmitted more completely to the bladder than to the urethra.

Both phenomena are illustrated in Figures 2 and 3. This behaviour of urethral closure

Table 2. Urethral values with stress (mmHg)

	Light coughs (≈ 15 mmHg)				Moderate coughs (≈ 30 mmHg)			
	Continent (n = 10)		Stress incontinent (n = 11)		Continent (n = 10)		Stress incontinent (n = 11)	
Bladder content (ml)	100	300	100	300	100	300	100	300
A	44.4	41.2	21.2	20.9	44.4	41.2	21.2	20.9
B	41.5	36.6	19.0	16.9	38.0	34.0	15.3	13.2
	(15.34)	(17.82)	(5.20)	(5.74)	(15.68)	(17.05)	(5.41)	(5.15)
C	37.7	32.3	15.5	13.5	26.2	23.0	3.1	3.0
B-C	3.8	4.3	3.5	3.4	11.8	11.0	12.2	10.2
	(1.48)	(1.34)	(0.69)	(0.81)	(3.39)	(2.75)	(3.63)	(2.22)
A-B	1.6	3.1	0	1.27	6.1	5.7	3.3	3.5
	(5.32)	(6.51)		(2.83)	(4.93)	(5.54)	(4.56)	(6.50)
A-C	6.7	8.9	5.7	7.4	18.2	18.2	18.1	17.9

	Strong coughs (≈ 50 mmHg)				Maximum coughs (≈ 70 mmHg n = 8)			
	Continent (n = 10)		Stress incontinent (n = 11)		Continent (n = 10)		Stress incontintent (n = 11)	
Bladder content (ml)	100	300	100	300	100	300	100	300
A	44.4	41.2	21.2	20.9	48.9	43.9		
					(13.67)	(18.92)		
B	32.3	29.7	12.0	10.0	33.9	25.0		
	(15.94)	(14.84)	(5.39)	(4.82)	(17.3)	(15.04)		
C	15.5	11.7	-6.4	-7.2	10.5	1.5	No maximum coughs were obtained from the stress-incontinent women	
B-C	16.8	18.0	18.4	17.2	23.3	23.5		
	(6.75)	(5.64)	(3.43)	(3.73)	(5.50)	(3.94)		
A-B	10.4	9.8	5.2	7.2	13.1	16.9		
	(5.54)	(7.86)	(6.15)	(4.51)	(10.06)	(6.71)		
A-C	28.9	29.5	27.6	28.1	38.4	42.4		

A-B values are corrected for S (see text)

Student's t-test has been used for the statistical analysis ($p < 0.01$)
The data are mean values, followed by the standard deviation in parenthesis

pressure under stress was similar in stress-incontinent and continent women.

Values at Rest (Table 1)

Maximum urethral closure pressure at rest differed greatly between stress-incontinent and continent women ($p < 0.01$). All severely stress-incontinent women had closure pressures of approximately 20 mmHg with small individual variations. Closure pressure in the continent group varied more widely although it was never as low as in the incontinent group.

Functional urethral length at 300 ml bladder content was shorter in stress-incontinent women ($p < 0.01$).

Values under Stress (Table 2)

As mentioned above, maximum closure pressure between coughs in a "cough profile" (B) was not as high as the corresponding closure pressure in the profile at rest (A). The difference, A-B, seemed to be due to an inability of the urethra to maintain normal tone when coughs came with a frequency of one per second (Figs. 3 and 5). Because some women do strain a little involuntarily during the "cough profiles" (so increasing bladder pressure S), correction was made for this to exclude error in the A-B values. As can be seen from Table 2, A-B was proportional to the strength of the coughs and was present in both continent and incontinent women from moderate coughs onwards.

The instant reduction of closure pressure right at the moment of a cough was seen in both groups too. Maximal closure pressure fell from B to C. B-C was proportional to the strength of the coughs and seemed to be of the same magnitude in both continent and stress incontinent women.

The total loss of closure pressure with repeated stress (A-C), consequently was of the same magnitude both in continent and stress-incontinent women (Table 2). As the maximal closure pressure at rest (A) in stress incontinence was significantly lower than in continence, the dynamic closure pressure, C, i.e. the margin between urethral closure pressure and the leakage threshold, reached zero sooner. Table 2 illustrates that C was negative already with strong coughs in the stress-incontinent women, while the continent women still had some margin left with maximum coughs.

Student's t-test has been used for the statistical analysis ($p < 0.01$).

DISCUSSION

In continent women the urethra is attached to the symphysis by the paired posterior and the single anterior pubo-urethral ligaments (10, 11). From beneath it is supported by part of the pelvic fascia (8). The elastic posterior ligaments permit a moderate descent of the bladder neck at micturition and straining, while the dense collagen anterior ligament fixes the external urethral meatus to the symphysis. The intra-urethral pressure is dependent on the tone of the smooth and striated muscles in the urethral wall and probably also upon the surrounding supporting tissues (9). The closure pressure is maintained at a high value in the middle part of the urethra and decreases rapidly proximally and distally (6). A normal urethral pressure profile recorded in a perfectly continent women may have the appearance shown in Figure 4. A typical profile of a stress-incontinent woman is also reproduced for comparison, illustrating its short maximum pressure plateau and low closure pressure.

In these respects the findings confirm earlier investigations (4, 7). The altered appearance of the profile in stress incontinence indicates a marked loss of tone of smooth muscle inside and in the immediate vicinity of the wall of the proximal urethra, physiologically rendering the uppermost fourth of the urethra part of the bladder. This loss of tone is accompanied by descent of the bladder neck region, due to impaired support from the surrounding tissues. Damaged blood supply during pregnancy, delivery or simply ageing might be the explanation for both phenomenon. but it is also plausible that mechanical injury to the supporting tissues is primary and the lost tone a secondary phenomenon.

In continent women, pressure transmission has been supposed to be equally good to both the bladder and the urethra, resulting in an unchanged closure pressure on straining (4). However, this did not seem to be the case. On the contrary, both continent and stress-incontinent women turned out to have incomplete pressure transmission. The magnitude of the pressure loss from abdomen to functional urethra was about 35 %, irrespective of bladder content. Thus the marked descent of the bladder neck during coughing in stress-incontinent-women seemed not to lead to any appreciable deterioration of pressure transmission compared with that seen with the moderate descent observed in the continent women. In a functional sense the position of the urethra is no more "extrapelvic" in stress incontinence than in continence. Pressure is lost along the cavum Retzii, pre-urethral space and the urethral wall in both conditions. Because the closure pressure in continent women was high at rest, the margin above the incontinence threshold was sufficient to avoid leakage even at maximum straining.

The margin above the leakage threshold is also influenced by the extent to which the initial urethral closure pressure is reduced after repeated coughs. After sudden stress the urethral pressure, instead of returning immediately to the initial level, recovers slowly over a few seconds, the length of recovery time being proportional to the degree of stress (Fig. 5). If a new pressure increase occurs before the initial resting tone has been restored, the margin at the time of the new stress will be smaller. Therefore stress-incontinent women are less at risk of urinary leakage at the first compared with, say, the fourth of a series of repeated efforts, e.g. coughing, running, climbing stairs. Thereafter the urethral pressure between coughs remains at a constant level and there is no further reduction of the dynamic closure pressure with constant efforts.

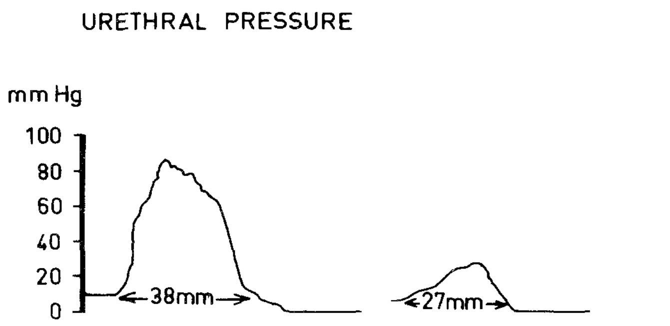

Fig. 4. Urethral pressure profile in patients with perfect continence and stress incontinence

Some smooth muscle cells have been shown to relax in response to certain frequencies of stimulation (1). It is possible that the sudden distension of smooth muscle cells surrounding the urethra and involved in its fixation to the symphysis results in such a relaxation. This phenomenon clearly occurred in both continent and incontinent women, although it seemed to be more pronounced in the former. The magnitude of this kind of loss of smooth muscle tone could not be calculated precisely. The differences between individuals were great and the loss was proportional to the strength of the coughs.

In conclusion, the dynamic urethral maximum closure pressure is dependent on the initial closure pressure at rest, the degree of loss of smooth muscle tone and the degree of transmission of pressure from abdomen to functional urethra. The total reduction of closure pressure with a cough (A-C) may amount to as much as 50% of the

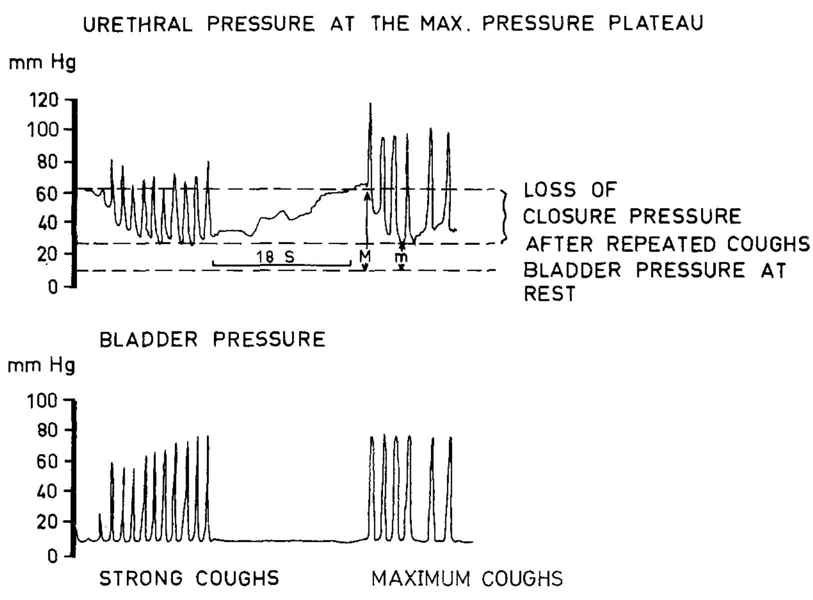

Fig. 5. Decrease in urethral pressure after repeated coughs. Notice the slow recovery. M = initial margin above leakage threshold m = final margin above leakage threshold

intensity of the cough itself. Only the initial closure pressure at rest was seen to differ greatly between continent and stress-incontinent women. It takes a closure pressure at rest of at least 25 mmHg to contain an effort corresponding to a sudden increase in intra-abdominal pressure of 50 mmHg. None of the stress-incontinent women had such a high closure pressure value at rest, while all the continent women had values above 25 mmHg. The magnitude of the urethral closure pressure at rest therefore seems to determine the degree of continence or stress-incontinence.

CONCLUSION

Pressure transmission from abdomen to urethra is not complete in either continent or stress-incontinent women. During sudden stress there is a loss of smooth muscle tone in the functional urethra itself, probably as a result of relaxation caused by distension. The total loss of closure pressure in a dynamic situation was of approximately the same dimension in continence and stress incontinence. This leaves the urethral closure pressure at rest as the most important determinant for the degree of continence in response to stress.

REFERENCES

1. Apter, J. T., Graessly, W. W.: A physical model for muscular behaviour. Biophysical Journal 10, 539 (1970)
2. Asmussen, M., Ulmsten, U.: A new technique for measurements of the urethral pressure profile. Acta Obstetrica et Gynecologica Scandinavica 54, 385 (1975)
3. Asmussen, M., Ulmsten, U.: Simultaneous urethrocystometry with a new technique. Scandinavian Journal of Urology and Nephrology 10, 7 (1976)
4. Enhörning, G.: Simultaneous recording of intra-vesical and intra-urethral pressure. Acta Chirurgica Scandinavica (Suppl.) 276, (1961)
5. Ingelman-Sundberg, A.: Urininkontinens hos kvinnan. Nordisk Medicin 50, 1149 (1953)
6. Öbrink, A., Bunne, G., Ulmsten, U.: The urethral pressure profile in continent women. Acta Obstetrica et Gynecologica Scandinavica 56, 525 (1977)
7. Öbrink, A., Bunne, G., Ulmsten, U., Ingelman-Sundberg, A.: Pressure-studies before, during and after pubococcygeal repair for stress incontinence. Acta Obstetrica et Gynecologica Scandinavica 57, 49 (1978)
8. Olesen, K. P., Grau, V.: The suspensory apparatus of the female bladder neck. Urologia Internationalis 31, 33 (1976)
9. Plevnik, S.: Model of the proximal urethra: measurements of the urethral stress profile. Urologia Internationalis 31, 23 (1976)
10. Zacharin, R. F.: The suspensory mechanism of the female urethra. Journal of Anatomy 97, 423 (1963)
11. Zacharin, R. F.: The anatomic support of the female urethra. Obstetrics and Gynecology 32, 754 (1968)

G. Bunne, M.D.
Department of Obstetrics and Gynaecology
Karolinska Institute
Sabbatsbergs Hospital
S-10401 Stockholm 60
Sweden