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Pressure Transmission to the Pre-Urethral Space in Stress Incontinence

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Summary. Pressure transmission from the abdomen to the pre-urethral space has been studied in stress-incontinent women and in some women following pubococcygeal repair for stress incontinence. Pressure was recorded at different levels of the pre-urethral space and simultaneously in the bladder. Simultaneous measurements inside and outside the urethra at different levels above the external urethral meatus showed that an intra-abdominal pressure rise was transmitted via the pre-urethral space to the urethra. Pressure was transmitted almost in full to the surroundings of the lower-most part of the bladder, but outside the functional urethra, transmission was successively more defective along the urethra towards the external meatus. Therefore, a short functional length and a distal maximal pressure plateau in the urethra, as in stress incontinence, is a disadvantage. Pressure losses amount to 1/3 or more. Pressure transmission could be improved to "supranormal" values by establishing firm support for the urethra, thereby allowing a minimum of rotational descent with stress and providing good counterpressure.

Key words: Urodynamics - Urinary stress incontinence.

Urinary leakage at rest is prevented by the pressure in the urethra being higher than the intravesical pressure. 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 is dependent on the tone in the urethral wall and on the urethral supporting tissues (5, 6). A sudden rise of the intra-abdominal pressure results in an equally large increase in intravesical pressure and leakage of urine occurs when this exceeds urethral closure pressure, if the intra-urethral pressure does not also rise. Enhörning found in 1961 that the intra-abdominal pressure increase produced by a cough is transmitted to the "intrapelvic" part of the urethra (4). He suggested that in stress incontinence leakage arises from defective abdominal pressure transmission. Owing to a lowered position of the urethra, the pressure increase transmitted to it is reduced or eliminated, whereas continent women have adequate transmission thanks to the normal retropubic position of the urethra. In stress incontinence the bladder pressure may therefore exceed urethral pressure, and urine leakage occurs. However, in comparisons between continent and stress-incontinent women defective urethral pressure transmission of similar magnitude was found in both groups (3). Irrespective of the degree of continence or stress incontinence, the pressure loss amounted to approximately 35 % of the particular increase in intra-abdominal pressure (3). We have also found that pressure transmission can be improved to some extent by the surgical provision of a firm floor beneath the urethra. After pubococcygeal repair the pressure loss was only 20 %; an improvement sufficient to achieve continence (2). Presumably, the greatest pressure loss occurs in the pre-urethral tissues and posteriorly due to the compliance of the anterior vaginal wall and the pelvic fascia beneath the urethra. To confirm the pre-urethral pathway of pressure transmission and to estimate the pressure loss across the urethral wall,

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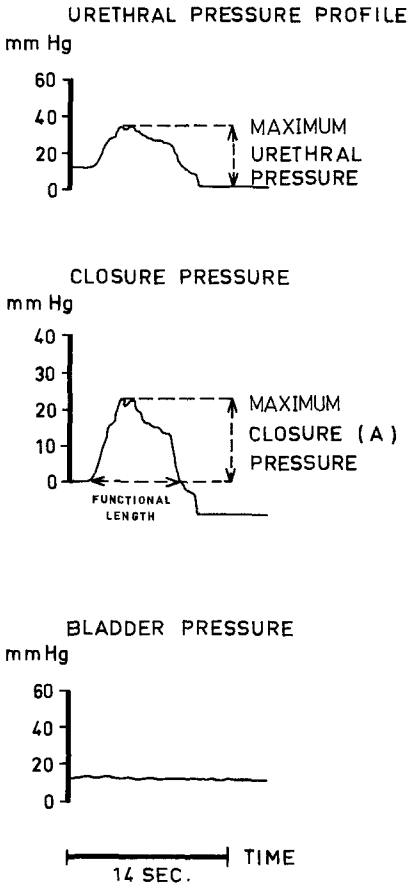

Fig. 1. The three simultaneously recorded parameters

simultaneous pressure measurements inside and outside the urethra at different levels during coughing have been performed in stress incontinent women. Simultaneous recordings of the intra-vesical pressure and the pressure at different levels above the urethra were also obtained before and immediately after pubococcygeal repair, to investigate the extent to which pressure is transmitted through the pre-urethral space.

PATIENTS AND METHODS

Seven women, mean age 50 years, with severe stress incontinence were examined immediately before operation. First, the urethral pressure profile was recorded with the equipment for simultaneous urethrocystometry (1), i.e. a thin, semiflexible Dacron catheter with two microtransducers, connected to amplifiers and a recorder. Electronic subtraction derived the difference between the recorded pressures (Fig. 1). This catheter remained in the bladder. A similar catheter was introduced with a thin trocar for 4-5 cm into the pre-urethral space after a minimum of local anaesthesia (1-2 cc lidocaine) had been applied in the mucosa. The intravesical and the pre-urethral pressures and the difference between them, were recorded at a bladder content of 200 ml. The patients were asked to cough repeatedly, first lightly, and then more vigorously. The first catheter remained in the bladder while the preurethral one was withdrawn distally in a stepwise manner with coughs and recordings centimetre intervals. In four cases, the catheters werewith drawn simultaneously through the urethra and the pre-urethral space, recording coughs at centimetre intervals. In five patients the examination was repeated (excepting this last procedure) after pubococcygeal repair had been completed.

RESULTS

Preoperative

The ratio between the pre-urethral and the intravesical pressure with a cough is shown in Table 1. Four cm into the pre-urethral space, that is just outside the bladder neck, the pressure increase almost equals that in the bladder. This indicates almost complete pressure transmission to the pre-urethral space at this point. Further distally, transmission becomes more and more incomplete as can be seen from the diminishing ratio between pre-urethral and intravesical pressures.

The relation between the urethral pressure profile and the pressure in the pre-urethral space at a cough is shown in Figure 2. The profile is representative not only of the stress-incontinent women in this study, but also for stress-incontinent women in general (3, 6). The maximum pressure plateau of the urethra is located approximately 1-2 cm from the external urethral meatus (EUM). Thus pressure transmission is not complete to that part of the urethra which includes the zone of maximum closure pressure. This in turn will result in a reduction in closure pressure during stress.

The intra-abdominal pressure increase with a cough may possibly reach the urethra from above, from beneath or from the bladder via the urethral wall. Table 2 shows the relationship between the pre-urethral and the intra-urethral pressure at the same levels above the urethral meatus as before. Since pressure in the pre-urethral space is always higher or equal to the corresponding intra-urethral pressure with a cough, the theory

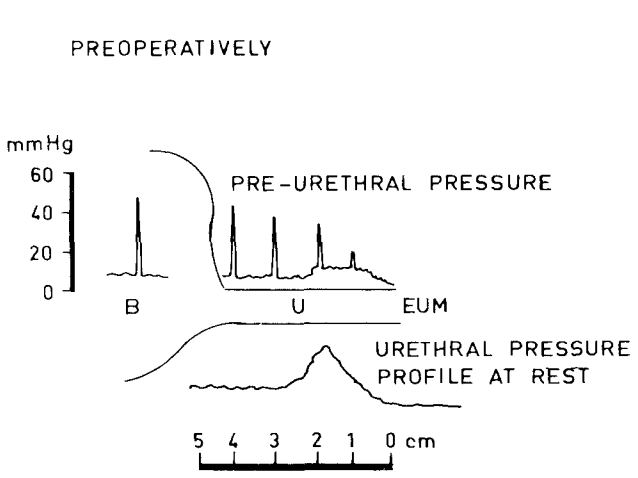

Fig. 2. Pressure transmission to the pre-urethral space and the functional urethra in stress incontinence.
B = bladder U = urethra EUM = external urethral meatus

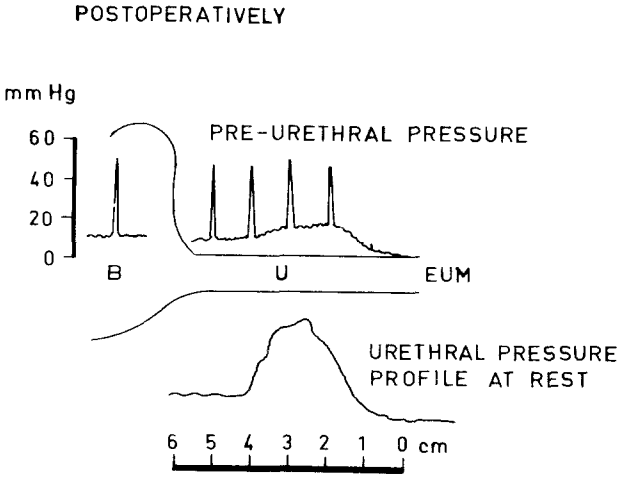

Fig. 3. The pressure transmission to the preurethral space immediately after pubococcygeal repair.
B = bladder U = urethra EUM = external urethral meatus

Table 1. The preoperative ratio: pre-urethral pressure/bladder pressure

Level above the external urethral meatus (cm)	4	3	2	1
	18.5/30	21.5/30	13.5/30	5/30
	38.5/40	33/40	30/40	17/40
	25/30	25/30	18.5/30	0/30
	40/40	37.5/40	39/40	18/40
	38/40	37/40	26/40	10/40
	34/40	20/40	20/40	9.5/40
	40/40	27/40	18/40	4/40
mean	89 %	77 %	63 %	23 %

The data are pre-urethral pressure increase (mmHg)/intravesical pressure increase (mmHg) at the different levels above the level of the external urethral meatus for each of the seven patients. The mean degree of pressure transmission (%) to the pre-urethral space is indicated.

of a pressure transmission via the pre-urethral space seems to be supported.

Postoperative

Postoperatively, immediately after suturing of the bladder ligaments and construction of the muscle sling under the urethra, it is elevated and somewhat extended. Compared to the preoperative state its maximum pressure plateau begins more than half a cm more proximally when measured from the external urethral meatus (6). Since the maximum pressure plateau is related to the suspensory

Table 2. Pre-urethral pressure/urethral pressure (mmHg)

Level above the external urethral meatus (cm)	4	3	2	1
	33/40	50/40	33/30	0/0
	20/20	20/20	20/15	5/5
	40/40	40/40	50/40	-
	52/60	63/60	74/60	10/5

At 4 cm one receptor is in the bladder and one outside the bladder neck. The loss across the urethral wall itself seems to vary between 0-25 %.

Table 3. The postoperative ratio: pre-urethral pressure/bladder pressure

Level above the external urethral meatus (cm)	5	4	3	2	1
	19/20	28/30	25/30	16/40	0/20
	13/15	15/15	20/20	20/20	0/20
	-	35/40	34/40	33/40	19/40
	-	30/30	30/30	30/30	0/30
	30/30	30/30	30/30	17/30	0/30
mean	94 %	96 %	94 %	76 %	10 %

The mean degree of pressure transmitted to the preurethral space is indicated (%).

ligaments of the urethra (5, 6), the pre-urethral space has a different appearance post-operatively and the maximum pressure plateau is located 2-3 cm proximal to the external urethral meatus, compared with 1-2 cm pre-operatively (Fig. 3).

We know from earlier studies (6) that these changes are temporary and disappear within 3 months of the operation. By then both the functional length and the maximum closure pressure have returned to preoperative values. The immediate postoperative conditions are shown in Table 3 and Figure 3. Pressure appears to be transmitted more completely to the pre-urethral space postoperatively which in turn means that closure pressure will be better maintained during stress.

DISCUSSION

It is obvious that pressure is transmitted from the abdominal cavity, via the bladder and cavum Retzii to the pre-urethral space and across the urethral wall to the urethral lumen. Bladder pressure has been found to be higher than pre-urethral pressure, which itself was higher than intraurethral pressure during sudden stress. In the cavum Retzii the pressure increase equalled that in the bladder, but along the urethra the pressure transmission progressively decreased. The pressure at rest in the pre-urethral tissues showed an abrupt increase approximately 2 cm proximal to the level of the external urethral meatus. This corresponds to the urethra's firmest

attachment to the symphysis and a greater density and tone of the pre-urethral tissues (7). This area also corresponds to the maximum plateau of the urethral pressure profile (5, 6). At this point the abdominal pressure transmitted to the pre-urethral space during coughing was only about 2/3 of the pressure increase in the bladder (Fig. 2). This coincides with earlier finding that the transmission loss amounted to 35-40 % (3). At a point 4 cm proximal to the level of the external urethral meatus, i.e. above the bladder neck, transmission approached. 90 %, at 3 cm it was approximately 80 % but at 2 cm, as mentioned above, it was only about 65 % and at 1 cm only a minor increment of intra-abdominal pressure reached the pre-urethral space.

Relating these findings to the functional length of the urethra gives rise to some theoretically interesting conclusions. Stress incontinence is characterised by a short functional length, due to a loss of tone in the proximal urethra (6). The point of maximum urethral pressure lies 1-2 cm inside the external urethral meatus and at 3 cm urethral pressure equals bladder pressure. Therefore, pressure transmission will be incomplete even at the beginning of the functional urethra. Continent women theoretically ought to have a somewhat better pressure transmission to their maximum urethral pressure plateau because this extends more proximally, being located 1.5-2.5 cm inside the external meatus (6). However, this difference is probably too small to be of any substantial importance clinically, although in general it is an advantage to have a long functional urethra with a proximally located maximum pressure plateau. With a distally located maximum pressure plateau losing more than 1/3 of transmitted abdominal pressure and an average maximum closure pressure of 20 mmHg, an effort which increases the intra-abdominal pressure by more than 60 mmHg will cause leakage. In reality, leakage occurs with less effort than this owing to additional losses of urethral pressure in the dynamic situation (3). The loss across the urethral wall itself seems to be small. There is no reason why this elastic structure, consisting mainly of smooth muscle layers, should offer any resistance to pressure unless scarring is present.

When the bladder ligaments had been sutured beneath the bladder neck and a muscle sling had been created under the proximal part of urethra, i.e. pubo-coccygeal repair, conditions were different. Pressure transmission to the surroundings of the proximal urethra was improved (Fig. 3). The tendency for pressure losses to become greater distally along the urethra persisted, but was less marked than pre-operatively. In the area of maximum urethral pressure, 80-90 % of an intra-abdominal pressure rise reached the pre-urethral space, although below this level the transmission diminished fairly abruptly. The pre-urethral space is outlined by the symphysis pubis anteriorly, the bladder and cavum Retzii superiorly, the posterior pubo-urethral ligaments and the levator muscles laterally and the urethra, pelvic fascia and the anterior vaginal wall postero-inferiorly. The firm anterior pubo-urethral ligament fixes the external urethral meatus to the symphysis (7, 8). Undoubtedly, the urethra is the most yielding structure under normal conditions. The firm support beneath the urethra post-operatively permits almost no downward rotation on straining, and the constructed "floor" ensures good counterpressure. It seems likely that the degree of pressure transmission depends chiefly on whether this "floor" of the pre-urethral space is firm or elastic. Providing an extremely solid floor under the urethra seems to be the only way of improving pressure transmission to values above normal. This seems to be more important than elevation of the bladder neck in itself. Furthermore, improving pressure transmission to the urethra appears to be essential for curing stress incontinence, since no treatment has been able to significantly increase the low closure pressure at rest, which is the main reason for leakage occurring in a dynamic situation (3).

CONCLUSION

A rise in intra-abdominal pressure is transmitted unchanged to the bladder and to the cavum Retzii, but diminishes progressively in the pre-urethral space along the urethra in stress incontinence. The loss of pressure in the pre-urethral space is chiefly dependent on the compliance of the pelvic fascia and the anterior vaginal wall beneath the urethra. Pressure transmission to the functional urethra is defective, the loss amounting to approximately 1/3 or more of an increase in the intra-abdominal pressure. Because of pressure transmission diminishing distally, a long functional urethra with a proximal maximum pressure plateau, as in continent women, seems to be favourable.

Pressure transmission can be improved considerably by the surgical provision of a firm floor beneath the urethra.

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