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URETHRAL PRESSURE PROFILE IN CONTINENT WOMEN FROM CHILDHOOD TO OLD AGE

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Abstract. One hundred and sixty-nine urinary continent females were examined with simultaneous urethrocystometry, using a dual microtip-catheter. It was shown that the maximum urethral pressure and the urethral length increased from infancy to the age of 20 – 25 years. Thereafter, the values of these parameters decreased with increasing age. The bladder pressure remained constant in the different age groups.

In six women, aged between 20 and 25 years, the parameters were measured three times during a menstrual cycle. No correlation between the fluctuating estrogens, gestagens, catecholamines and the urethral pressure or the urethral lengths was found.

During the last two decades methods have been evolved for determining the urethra's intraluminal pressure, which is important for urinary continence (4, 5, 7, 9). The difference between maximum urethral pressure (MUP) and bladder pressure (BP) is defined as closure pressure (CP). When CP is positive, the individual is continent; when it is negative or zero, she is incontinent.

Three main methods have been employed for the measurement of urethral pressure:

1. Fluid-filled baloon catheters (9).
2. Open-end catheters with constant flow (6, 11).
3. Pressure transducers placed intraluminally in the urethra (3, 4, 5).

Although the first two methods have been used extensively in the past, the equipment is difficult to handle and calibrate. Furthermore, with open-end catheters with constant flow, problems arise in determining the urethral closure pressure, which is important when investigating urinary incontinence. Besides, both methods may give a great variety of artifacts.

The microtransducers measure the pressure in a small area with high accuracy and reproducibility. With a dual catheter, bladder pressure and urethral pressure can be measured simultanously, at rest, under stress conditions, and during filling of the bladder.

Each method has its own "normal" value. With open-end catheters the pressure comprises both the intraluminal pressure and the resistance to flow. With baloon catheters the measuring section is usually so large that the recording represents the sum of different pressures over a rather long distance. This impedes calculations of the true intraluminal pressure. The microtransducer measures just the intraluminal pressure in an extremely small area (approximately 0.75 mm^2). The aim of the present investigation was to determine UP, BP and CP — as measured by microtransducer catheters — in healthy women of different ages. Furthermore, these parameters were studied during the menstrual cycle, since it has been claimed that they may fluctuate with estrogen and gestagen levels (10).

MATERIAL AND METHODS

The study comprised 169 healthy women. They were divided by age into thirteen groups: 6 – 15 years, 16 – 20, 21 – 25, 26 – 30, 31 – 35, 36 – 40, 41 – 45, 46 – 50, 51 – 55, 56 – 60, 61 – 65, 66 – 70, and > 71. The youngest girls had been examined because of symptoms indicating urinary incontinence; those with no objective signs of incontinence (see below) were included in the present study.

The middle age-groups consisted mainly of healthy volunteers with no urological symptoms. Some women had been admitted to the department because of carcinoma in situ of the cervix. Bacterial cultures were negative in all patients and cystoscopy was normal. The subjects were examined with simultaneous urethrocystometry, including measurements of the urethral pressure profile according to the Asmussen-Ulmsten technique (3, 4, 5). The bladder was filled at a rate of 25 ml/min with saline, heated to body temperature. Three consecutive urethral pressure profiles (UPP) were registered at rest at a bladder volume of 200 ml. All patients were examined in a semi-seated position.

Table I. *MUP, BP and CP in different age groups.*

	Age groups												
	6–15	16–20	21–25	26–30	31–35	36–40	41–45	46–50	51–55	56–60	61–65	66–70	≥71
Parity	0	0.05	0.04	0.83	1.90	2.11	1.78	1.75	1.81	1.57	1.28	1.50	1.57
MUP*	97±6	106±5	110±4	94±5	104±8	81±7	89±5	80±8	84±6	82±7	68±5	66±9	62±6
BP*	20±2	21±1	20±1	21±1	20±2	16±2	22±1	17±2	24±1	21±2	22±3	17±1	24±3
CP*	77±7	85±4	90±4	73±5	84±8	65±7	67±5	63±7	60±6	61±7	46±7	49±9	38±5
No.	12	18	24	18	11	9	18	12	15	14	7	4	7

*Mean ± SE

Urinary continence was recognized in three ways:
1. A negative history of urinary stress incontinence.
2. No observed leakage of saline from the outer urethral meatus.
3. A positive urethral closure pressure both at rest and at stress.

Six nulliparous women, mean age 22 years (20–25), were investigated in the same manner at various phases of the menstrual cycle, i.e. early, at midcycle and late. On these occasions blood samples were taken to determine total estrogens, progesteron and the catecholamines: dopamine, adrenaline and nor-adrenaline. The techniques for these determinations have been described elsewhere (14).

Calculated parameters. The mean of three consecutive UPPs at a bladder volume of 200 ml was determined and used to calculate MUP, BP, CP, FUL and AUL (Fig. 1).

Statistics. The variations in MUP and BP in different age groups were tested for significance by means of one-way analysis of variance ("F-test") (1).

Urethral length (FUL and AUL) was analyzed by Student's t-test.

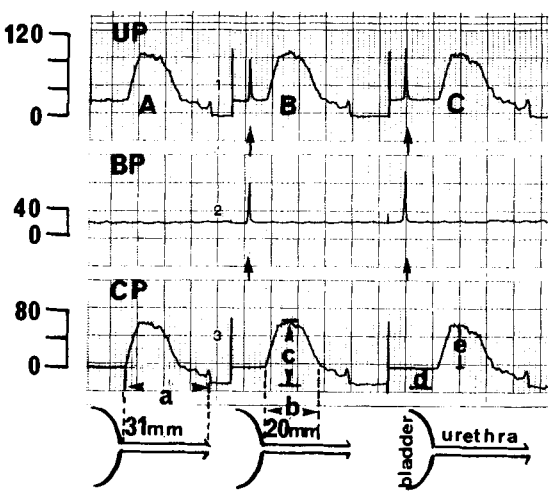

Fig. 1. A, B and C represent three consecutive urethral pressure profiles in a female. The arrows indicate the presence of both transducers in the bladder, as the difference between UP and BP at that point is zero.
UP = Urethral Pressure.
BP = Bladder Pressure.
CP = Closure Pressure.
a = absolute urethral length.
b = functional urethral length.
c = maximum urethral pressure.
d = bladder pressure.
e = closure pressure.
Paper speed = 2.5 mm/sec.
Catheter withdrawal speed = 2.5 mm/sec.
Pressures in cm H_2O.

RESULTS

Urethral pressure. As seen from Table I and Fig. 2, MUP increased from a mean of 97 cm H_2O (range 59–115) in the youngest age group to 110 cm H_2O (range 76–154) in the age group 21–25 years. This increase was not statistically significant. After the age

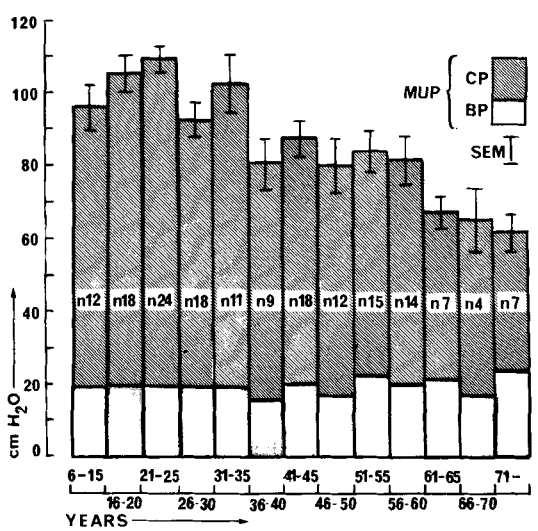

Fig. 2. Maximum Urethral Pressure (MUP), Bladder Pressure (BP) and Closure Pressure (CP) in 169 healthy females in different age-groups. SEM = Standard Error of the Mean.

Table II. *Urethral lengths in different age groups.*

	Age groups											
	6–15	16–20	21–25	26–30	31–35	36–40	41–45	46–50	51–55	56–60	61–65	66–70	≥71
FUL*	27±2	27±1	30±1	30±2	29±2	27±2	27±1	31±2	28±1	29±1	25±2	23±2	26±2
AUL*	31±2	34±1	37±1	37±2	36±2	32±2	35±1	37±2	35±2	35±1	32±3	30±2	33±2
No.	12	18	24	18	11	9	18	12	15	14	7	4	7

*Mean ± SE

of 25 years MUP decreased with increasing age. For example the difference between the age group 21–25 years and women over 36 years was significant ($p < 0.01$). No definite decrease was found in relation to menopause.

Bladder pressure. The bladder pressure did not differ significantly between the age groups; it remained almost constant at 20 cm H_2O (at a bladder volume of 200 ml).

Closure pressure. Since BP was more or less constant, the closure pressure showed the same significant decrease with increasing age as MUP (Table I and Fig. 2).

Functional urethral length. FUL increased from a mean of 27 mm (range 18–41) in the youngest age group to a maximum of 31 mm (range 23–43) in the age group 46–50 years; it decreased thereafter to a minimum of 25 mm (range 18–36) at 70 years and older (Table II). These differences were significant ($p < 0.05$). The difference in FUL between women before and after the menopause was significant ($p < 0.05$).

Absolute urethral length. AUL showed the same tendency as FUL and the same statistical significance for shortening after the menopause. However, in all age groups AUL exceeded FUL by about 5–10 mm.

MUP, BP, CP, FUL, AUL and catecholamines during the menstrual cycle. No definite correlation was found between continence-maintaining parameters (MUP, BP, CP, FUL, AUL) and estrogen and gestagen levels during the menstrual cycle (Table III).

The catecholamines (dopamine, adrenaline and nor-adrenaline) showed very small variations during the menstrual cycle and could not be responsible for the variations in MUP during a series of measurements in the individual woman. Nor did they influence urethral length (Table III). Only one woman had a detectable level of dopamine.

Table III. *Dependence of estrogens, gestagens and catecholamines on the urethral pressure profile in six healthy nulliparae.*

Pat.	Age	Day[1]	MUP[2]	BP[2]	CP[2]	FUL[3]	AUL[3]	Estrogen[4]	Progesterone[4]	Adrenaline[4]	Noradrenaline[4]	Dopamine[4]
R. S.	22	7	135	24	111	27	36	0.30	1.7	0.1	1.1	–
		14	138	24	114	25	35	0.70	2.0	0.6	1.4	–
		22	141	24	117	27	37	0.61	14.1	0.6	1.0	–
M. N.	25	9	88	20	68	34	42	0.31	2.2	0.5	1.2	–
		12	79	16	63	31	44	1.24	1.6	0.4	1.7	–
		23	84	20	64	32	43	0.93	9.9	0.5	1.8	–
U. S.	20	17	125	28	97	30	42	0.98	2.3	0.5	0.8	–
		24	128	28	100	28	37	0.68	3.0	0.6	1.2	–
		59	116	28	88	27	36	0.90	26.9	0.6	1.0	–
I. H.	22	6	110	24	86	26	30	0.46	1.5	0.95	1.8	0.16
		12	124	24	100	26	28	0.76	2.0	1.16	1.7	0.6
		22	109	24	85	25	28	1.11	37.3	1.25	1.1	0.4
M. H.	20	8	134	28	106	29	34	0.18	1.3	1.3	–	
		12	125	24	101	30	34	0.21	2.4	1.2	2.9	–
		22	135	24	111	31	40	0.43	19.5	1.2	2.2	–
B. S.	21	9	120	20	100	32	36	0.26	1.1	0.7	1.4	–
		13	137	16	121	29	35	0.40	<1.0	0.7	1.1	–
		23	133	28	105	29	34	0.32	<1.0	0.7	1.7	–

[1]Day of cycle, [2]cm H_2O, [3]mm, [4]pmol/l.

DISCUSSION

The decrease in urethral pressure with increasing age was demonstrated in 1961 by Enhörning (9). It has been claimed that MUP is highest in childhood (7, 12). This study, however, shows an increase from infancy to adolescence, though the results do not provide any explanation for this. The increase does not seem to be related to puberty. If puberty (with an increasing production of estrogens) and the climacterium (with decreasing estrogen levels) did influence urethral pressure, a marked increase would be expected around puberty and a marked decrease after the age of 50. Moreover, one would expect a correlation between urethral pressure and estrogen levels during the menstrual cycle. The present study showed no such correlation, and the decrease in urethral pressure with increasing age was continuous. Furthermore, the estrogen level in ovulating women is much the same at 21 – 25 and 40 – 45 years of age (2, 17).

In an experimental study in the human female we found that blood pressure was responsible for ⅓rd of the maximum urethral pressure (15). The individual tracings revealed a more marked periurethral arterial pulsation in the youngest age groups compared with the older. The urethral pressure decrease is therefore more likely to reflect a loss of tonicity in the urethral wall and thicker vessel walls with increasing age, thereby diminishing pressure transmission to the urethral lumen.

Another study has shown that high doses of estrogens in postmenopausal women increase the maximum urethral pressure only slightly. Nor did the gestagen levels seem to influence MUP in these women (16).

In the present investigation, the six women examined during the menstrual cycle showed no correlation between estrogen levels and MUP. Neither was there any correlation between serum levels of the catecholamines dopamine, adrenaline, nor-adrenaline and MUP.

Parity might be one of the causes of the decrease in urethral pressure with increasing age. This could theoretically explain the onset of the decrease from 25 years of age. However, although the material is too small to be divided into parous and non-parous, the individual pressure tracings showed that MUP fell with increasing age even in the non-parous women.

The length of the urethra is held to be of great importance for continence (13). It is therefore of interest to find that urethral lengths do shorten after the menopause. In another study I found that high-dose estrogen treatment elicited a lengthening of the urethra but this lengthening did not correlate significantly with improvements in urinary stress incontinence (16).

At physiological levels, however, it may be concluded that estrogens and gestagens, as well as catecholamines, do not influence MUP or urethral length. This agrees with Ek *et al.*, who found no increase in MUP after therapeutic doses of estrogen in stress incontinent women (8).

According to Edwards and Malvern (7), MUP in healthy women, measured by open-end catheter with constant flow, can be calculated from the formula: 92 – age.

Pressures measured with the microtip-catheter are, however, higher as a rule than those obtained with open-end catheters. According to this study, maximum urethral pressure — measured by means of a microtip-catheter with 200 ml saline at body temperature in the bladder and the subject semi-seated — in healthy women after the age of 25 is 130 cm H_2O – age ± 20 cm H_2O.

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