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How to measure urethral elastance in a simple way

Elastance: definition, determination and implications

P. Thind, G. Lose, and H. Colstrup

Department of Urology, Rigshospitalet, University of Copenhagen, Copenhagen, Denmark

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Summary. The elastance of a biological tube describes the resistance of the latter to dilatation. It is defined as dP/dV, where dP is the pressure increase caused by the volume increase dV. Elastance is the reciprocal of compliance. Elastance in the female urethra can be estimated from the slope of the regression line of related values of pressure and cross-sectional area. In the present study, urethral elastance was calculated by measurement of the related pressures and cross-sectional areas during stepwise dilatation by a balloon and by determination of the pressure at which inflow through side holes in catheters with increasing diameters began. There was no difference between the elastance values obtained by the two methods. Due to the linear correlation found between pressure and cross-sectional area we conclude that urethral elastance can be estimated from measurements of urethral pressure at two or more related cross-sectional areas by a simple technique using e.g., 8F, 14F, and 20F catheters.

Key words: Elastance/compliance – Urethra – Women – Measurement

New techniques have recently been introduced that enable the measurement of urethral elastance, which is the reciprocal of compliance [3, 4, 10, 11]. The equipment used for such urethral measurements is rather complicated and not yet commercially available. However, clinical results have shown that urethral pressure (P_{ura}) can be described as a linear function of the cross-sectional area (CA). Thus, $P_{ura}(CA) = dP/dCA x CA + P_0$, where the slope of the line (DP/dCA) is the estimate of elastance and P_0 is the intercept (theoretical pressure in the non-instrumented urethra) [2, 7, 8]. Consequently, the linear function of P_{ura} and, hence, the elastance, may simply be estimated from measurements of the two related values for urethral pressure and CA.

The aim of the present study was to compare the elastance estimated from measurements of stepwise urethral dilatation by a balloon with that estimated from the determination of the perfusion pressure using catheters of different sizes.

Patients and methods

A total of 19 healthy women with a median age of 25 years (range, 21–33 years) volunteered for this study. None of them had urological or gynecological complaints. Measurements with the balloon catheter were performed using a specially designed, double-microtip transducer catheter [10, 11]. The tip sensor was placed in the bladder. The proximal sensor was placed in the urethra and covered with a water-filled cylindrical rubber balloon that was 1.5 cm long. Related values for pressure and the cross-sectional area (CA) of the balloon were obtained. The CA was measured according to the field-gradient principle [4, 10]. Pressure recordings obtained with a covered and uncovered proximal sensor were checked in a pressure chamber and found to be identical [10]. The balloon was connected to a 1-ml syringe, with which the former was inflated and deflated.

In nine women, measurements were performed by stepwise inflations of the balloon, with induction of the CA being increased by 5–10 mm^2 (Fig. 1A), or by one large inflation (Fig. 1B). The urethral pressure at equilibrium after induction of the CA was used. These measurements were performed at the bladder neck, in the mid-urethra (high pressure zone), and distally in the urethra. By each method of inflation, the CA of the balloon/urethra was changed from 20–30 mm^2 to 60–70 mm^2. In ten women, mid-urethral measurements were performed by stepwise inflation of the balloon and by determination of the height of a water column at which inflow through a catheter with side holes began. Catheter sizes of 3, 5, 8, 14, and 20 F were used.

Examinations were carried out with the women lying supine and with the bladder being empty. Informed consent was obtained from all volunteers, and the study was approved by the regional ethical committee. Methods, definitions, and units conform to the standards recommended by the International Continence Society except where specifically noted. When the method described above is used for the determination of elastance, only the CA changes. Consequently, the urethra can be considered to be a cylinder of indefinite length. Accordingly, in these calculations, elastance is expressed in centimeters of water per square millimeter (cm H_2O/mm^2).

Data on the bladder pressure, urethral pressure, and CA were registered, processed, and displayed on a 6-channel recording system (Disa Urosystem 21F162100). The frequency response of the amplifying system was 100 Hz and the paper velocity was 15 mm s^{-1}.

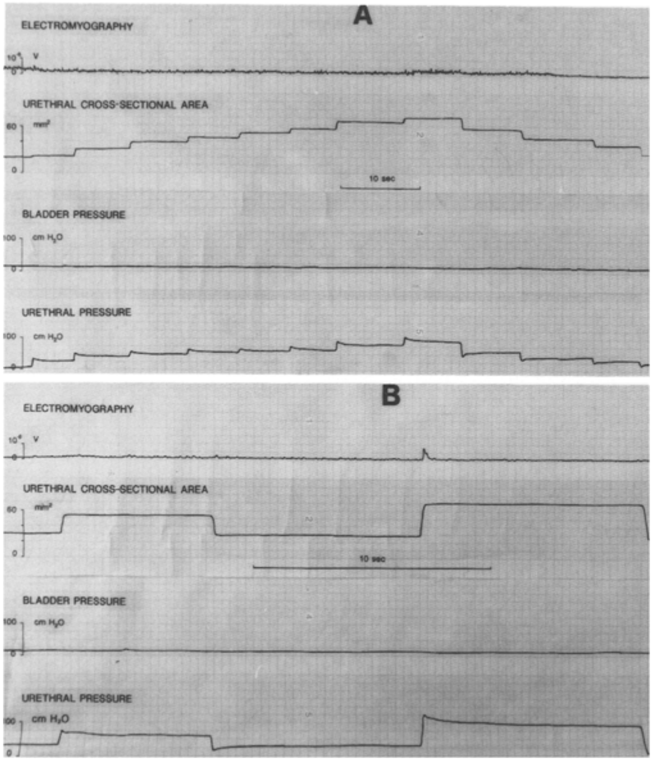

Fig. 1 A, B. Measurement of related urethral pressures and cross-sectional areas in a 24-year-old woman. **A** Stepwise induction of a cross-sectional area. **B** Induction of a cross-sectional area by one large step

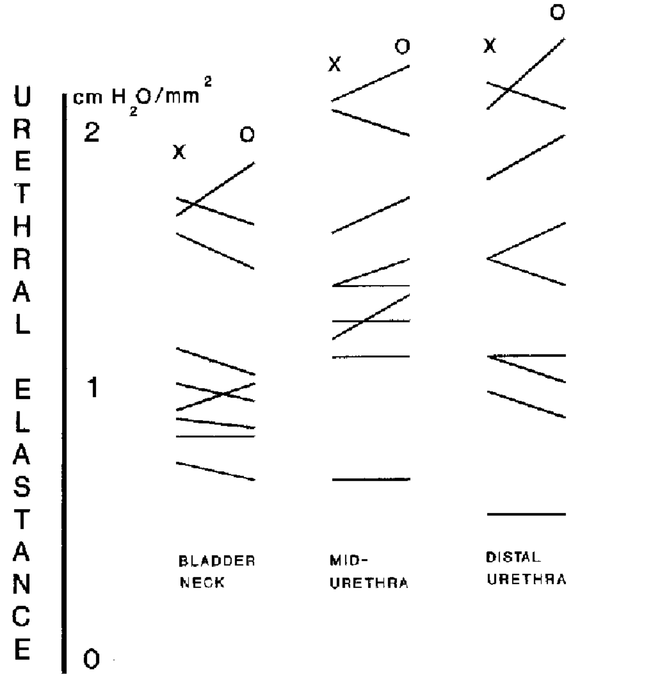

Fig. 2. Urethral elastance calculated from related pressures and cross-sectional areas induced stepwise (*x*) and by one large inflation (*o*)

The statistical analysis was based on standard non-parametric methods and the Wilcoxon test was used to analyze differences between the results obtained by the two methods. A value of $P < 0.05$ was considered to be statistically significant.

Results

Figure 1 presents the related urethral pressures and CAs measured using the balloon catheter. Table 1 shows the urethral pressure measured at a given small and large CA. There was no significant difference between the pressures obtained at comparable CAs using the two methods of balloon inflation. The elastance values estimated from measurements obtained using the two ways of inflation showed no significant difference (Fig. 2). Figure 3 demonstrates the urethral pressures in a 27-year-old volunteer as measured at different CAs using the balloon catheter and the catheters with side holes, and Fig. 4 shows the elastance values for ten volunteers as estimated from related pressures and the CA measurements obtained using the two types of catheters. No significant difference was observed.

Discussion

The present study revealed no difference in urethral elastance as estimated from the related values for pressure and CA that were obtained either by stepwise urethral dilatation with a balloon catheter or by dilatation using catheters of increasing size. The results show a linear correlation between the pressure and the CA over the total range of CA used. Accordingly, elastance could be estimated from a minimum of two related values, which should lie within a certain CA range to ensure accuracy. The deviations in urethral elastance obtained by the two methods are acceptable and lie within the range of

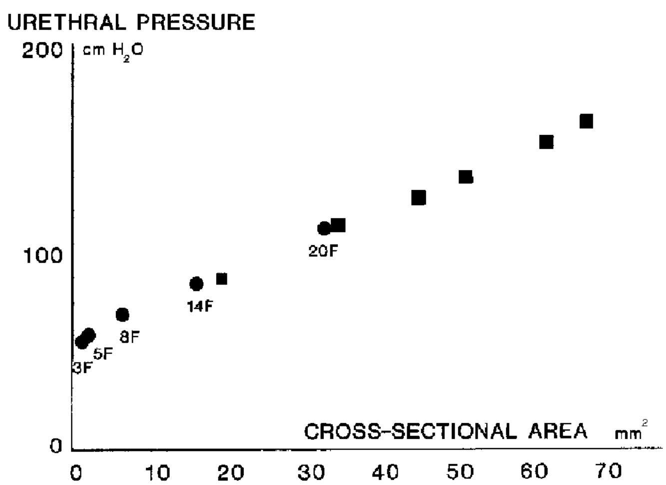

Fig. 3. Related urethral pressures and cross-sectional areas measured in a 27-year-old volunteer. ●, pressures determined as the height of a water column at which inflow through catheters with side holes was initiated; ■, pressures measured at increasing cross-sectional areas induced by a balloon

Table 1. Urethral pressure measured in 9 female volunteers at a given small (20–30 mm^2) and large (60–70 mm^2) cross-sectional area (CA) as induced in two different ways by balloon inflation. Percentile in brackets.

		Urethral pressure		
		Stepwise induction of CA	One large induction of CA	Deviation[a]
Bladder neck	1	30 (15, 50)	30 (16, 44)	0 (−5, 5)
	2	75 (55, 123)	75 (60, 120)	−3 (−5, 0)
Mid-urethra	1	77 (35, 90)	80 (37, 90)	1 (0, 4)
	2	125 (102, 185)	125 (105, 185)	0 (−5, 5)
Distalurethra	1	40 (25, 50)	33 (25, 50)	−5 (5, 0)
	2	107 (50, 127)	100 (50, 125)	−3 (−10, 4)

Data represent the median values, expressed in cm H_2O; numbers in parentheses indicate the 25th and 75th percentiles. 1, Small cross-section; 2, large cross-section

[a] The urethral pressure measured before (1) and after (2) one large inflation minus that measured at the same CAs during stepwise inflation

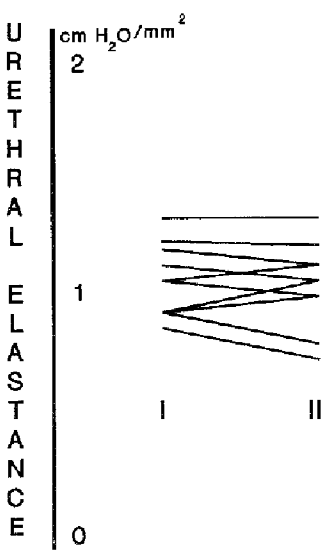

Fig. 4. Mid-urethral elastance calculated from measurements obtained by inflation of one balloon catheter (*I*) and by that obtained using increasing catheter sizes (*II*)

reproducibility previously determined for the balloon method [9], and the elastance values correspond to results previously reported in healthy women [2, 8]. The simple method using increasing sizes of catheters and elevation of the water level in a reservoir is consistent with data previously reported on urethral elastance [1, 14]. Although urethral pressure may vary according to the techniques used (perfusion, microtip, or balloon catheters), we suggest that elastance is not influenced if a given method is used consistently. For all techniques, it is important that the smallest CA be used first due to urethral hysteresis [3, 7].

Changes in the mechanical properties of the female urethra may lead to obstruction and/or incontinence [5, 8, 12, 14]. Conventional pressure profilometry is insufficient to assess the mechanical properties of the urethra, since this technique provides only one single pressure given by the CA of the catheter. Estimation of the elastance provides more information on the mechanical properties of the urethra, enabling discrimination between urethral hyperlaxity (decreased elastance) and urethral rigidity (increased elastance) in patients with genuine stress incontinence [8, 14]; consequently, urethral elastance may have important therapeutic implications [12, 14]. In both of these disorders, low urethral pressure would be found using conventional small diameter catheters. Elastance also seems to be useful in the assessment of drug actions on the urethra [6] and, possibly, in the diagnosis and location of obstruction [13].

Measurement of urethral elastance merits attention in the urodynamic workup of patients with voiding disfunction such as stress incontinence. The technique using catheters of different sizes can be applied to obtain two or three related values for urethral pressure and CA from which the elastance can be calculated. We suggest that 8-F, 14-F, and 20-F catheters be used.

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Peter Thind, MD
Dalso Park 2
DK-3500 Vaerlose
Denmark