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REVIEW

The Urethral Pressure Profile

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The mechanisms of micturition and the maintainance of continence continue to fascinate and challenge those with an interest in urodynamics (34). There is still a great need for objective data in the study of bladder and urethral function. Measuring urethral closure forces has proved more difficult than quantifying the dynamics of voiding, but the development by Brown and Wickham (5) of a simple method of obtaining a urethral pressure profile has renewed interest in such measurements.

The urethral pressure profile is a record of the pressure exerted by the urethral wall on a recording catheter as it is withdrawn from the bladder to the external meatus. It must be stressed that the urethral pressure profile is a 'static' measurement: it records urethral closure pressures with the bladder at rest and does not measure, and may bear no relationship to, the resistance offered by the urethra during voiding. The International Continence Society emphasises the point by suggesting the term Urethral Closure Pressure Profile (28) which, though more accurate, is rather inelegant and seems unlikely to be widely used.

MEASUREMENT OF URETHRAL PRESSURE

Modern methods of recording urethral pressure from a localised segment of urethra have largely superceded techniques of 'sphincterometry' which attempt to quantify urethral closure forces by measuring the pressure required to force fluid (or air) retrogradely into the bladder (3, 45). Most methods which measure a localised urethral pressure can be adapted to record a profile by drawing the recording device along the urethra. Commonly used techniques for urethral pressure measurement are:

i) Fluid Filled Balloons

Small catheter mounted balloons have been used for many years and are still favoured by some investigators (11, 12, 31, 38). The disadvantages of balloon techniques are that the balloon distorts the urethra, pressure is measured over a length of urethra related to the size of the balloon, and forces are exerted on the balloon from all directions (42). In practice the main drawbacks are difficulties in construction and calibration of the recording catheters (6, 30, 31).

ii) Side Hole Catheters with Perfusion

A simple catheter, closed at the distal end but with one or more side holes can be used to measure pressure exerted by the urethral wall (32). Brown and Wickham (5) devised an ingenious extension of this method which enabled a complete pressure profile to be simply and rapidly obtained. As fluid is slowly infused down the recording catheter the pressure required to maintain the flow is monitored by a standard transducer and chart recorder and this pressure should be equal to the pressure exerted by the urethral wall at the site of the catheter side holes. By withdrawing the catheter from the bladder, pressures from consecutive segments of urethra are recorded and a complete pressure profile obtained. Harrison and Constable (24) modified the method by introducing a 'catheter position transducer' and an X-Y recorder with the additional advantages that profiles can be superimposed and readily compared, accurate measurement of length can be made, and specific sites on the profile can be localised. In addition an infusion pump replaced the drip system providing a constant known flow rate through the catheter. The use of a motor driven system to withdraw the catheter at a constant rate (1, 16, 26) gives accurate length information without the need for an X-Y recorder but does not allow superimposition of profiles or the re-location of the catheter at a particular site. A further refinement has been the introduction of a double lumen profile catheter which allows bladder pressure to be recorded continously while the profile is obtained (19).

iii) Catheter Tip Transducers

In both methods (i) and (ii) the pressure transducer is located at a distance from the urethra and inaccuracies inherent in a fluid filled system such as delayed response time and damping due to air-bubbles and leakages may occur. It would therefore seem attractive to have the transducer located within the urethra and with advances in technology there is little difficulty in providing a microtransducer system (2, 42). However catheter tip transducers are heat sensitive and present their own problems with calibration in addition to high cost and limited life (2, 37).

PROFILE MEASUREMENTS

The most useful measurements which can be made from the urethral pressure profile are:

i) Bladder Pressure. This is recorded by the profile catheter initially and, ideally, is measured independently during the profile recording.

ii) Maximum Urethral Closure Pressure. This is the difference between bladder pressure and the maximal urethral pressure.

iii) Functional Urethral Length. This is the length of the profile over which the urethral pressure exceeds bladder pressure. In the female measurements can be made readily from the profile (accurate to $\pm$ 2 mm when the catheter position transducer is used (23)). Length measurements in the male are more difficult as the distal reference point is less readily defined (9, 23).

In addition to the above measurements suggested by the International Continence Society (28) there are two other profile features of significance:

iv) Bladder Neck Pressure. In the male a separate initial pressure rise and a prostatic plateau is often recognisable (1, 9, 23) and the difference between this pressure and bladder pressure can be recorded.

v) Profile Configuration. The shape of the profile should be observed and compared, although this is not easily quantified.

PROFILE THEORY AND PRACTICE

Although the Brown and Wickham technique has been widely used there has remained some suspicion of the assumptions made, doubts about its accuracy and controversy regarding normal values and clinical significance. The theory on which the technique is based was clearly explained in the original paper (5) and has recently been re-examined (4). An appraisal of the technique based on an analysis of measurements made in models concluded that the technique measures correctly the pressure exerted by the urethral wall against the catheter (33).

Perhaps the main area of unease and confusion has been the use of a fluid flow to measure a static pressure. In theory the flow element introduces a constant positive error to the pressure recorded which is approximately 1 cm H_2O for every ml min -1 infusion (4). At flow rates of the order of 2 ml min -1 commonly used the error is small and constant provided the flow remains unchanged. Although in practice several studies have shown results to be almost independent of flow rate (10, 14, 21) it is highly desirable that a standard rate of say 2 ml min -1 is adopted by all investigators.

The size of catheter used for profile measurements has been largely dictated by practical considerations, 8 and 10 Charriere being the most common. There have now been several studies indicating that the pressure recorded is largely independent of catheter size within the range 5-19 Charriere (5, 10, 14, 20, 21) but again it would be desirable to adopt a standard catheter size.

More recently axial rotation of the recording catheter has been shown to be a factor which may influence the reproducibility of profiles. In a series of experiments in dogs a marked rotational effect was found when the recording catheter had one side hole and was reduced as the number of side holes was increased up to eight (14). Most clinical studies reported have used catheters with at least two side holes (5, 10, 19, 23, 24, 26), but some have used catheters with only 1 side hole (17, 21). A catheter with multiple side holes records the lowest pressure applied to it which, while reducing rotational changes, also reduces the effective resolution of the profile. The observation of catheter rotation effects is an important one; in practice the commonly used catheters having between two and four side holes probably represent a good compromise for clinical measurements.

The speed of withdrawal of the recording catheter does not distort the profile provided the response time of the system is adequate (10, 14, 23). A slow steady movement of the catheter is desirable to minimise discomfort for the patient and avoid introducing reflex contraction of the pelvic floor or movement artefacts.

When a catheter position transducer is used it is easy to superimpose two or more profiles to check the reproducibility of the technique and extensive experience has shown that, performed with care, the results can be very consistent (10, 22, 23). The experimental error inherent in the method appears to be in the region of $\pm$ 5-10 cm H_2O (14, 20, 21).

Under general anaesthesia profile pressures may be higher or lower than with the patient awake (10, 23). When profiles from two groups, with and without anaesthesia, are compared, there are no significant differences (10) but it is unwise to conclude that general anaesthesia will not influence the results in an individual patient.

The Brown and Wickham technique is a sound and basically simple one, but like most clinical investigations the value of the information obtained is directly proportional to the care with which the test is performed.

PHYSIOLOGICAL VARIATIONS

i) Bladder Volume and Detrusor Activity

Glen and Rowan (19) have demonstrated the importance of knowing bladder volume when recording urethral profiles as maximum urethral pressure and profile length may change as the bladder is filled. A deterioration in the profile with bladder filling is of pathological significance (19, 22). Bladder volume can be recorded with a standard profile catheter but to record bladder pressure during profile recording a separate pressure line, placed suprapubically (13) or alongside the profile catheter, or a special double lumen catheter (19) is necessary. Profiles should be recorded with the bladder at rest as an uninhibited detrusor contraction may lower the profile pressure (19).

ii) Posture

Profiles are most conveniently performed with the patient supine and their knees drawn up or in the lithotomy position. Comparisons have been made between profiles obtained in the supine and erect positions (10, 21). On standing, abdominal, bladder and urethral pressures all rise, but the difference between bladder and urethral pressure (maximum urethral closure pressure) shows little or no change as intra-abdominal pressure is transmitted to both bladder and urethra.

iii) Age

Enhorning (11) noted that urethral pressures recorded by balloon catheters were lower in females over the age of 40 years. A significant negative correlation between age and profile pressure was found in both males and females by Harrison (23) and confirmed by Edwards for female patients (7) and Haubensack in both sexes (26). In males functional urethral length increases with age (23, 26) which correlates well with elongation of the urethra due to prostatic growth.

For meaningful comparisons of profile studies to be made the age of the population studied must be taken into account. One way to obviate age variation is to use the regression equation to convert profile pressures to a 'standard' age of, say, 50 years (23).

iv) Normal Values

A number of investigators have been able to obtain urethral pressures or profiles in volunteers or patients without disturbances of micturition (6, 7, 11, 23, 26, 41). These studies have shown a wide scatter of values of maximum urethral pressure, mostly within the range 20-120 cm H_2O. Differences in results from one series to another may reflect variations in technique, dissimilarity of age groups as well as the wide range of physiological normal. As a guide to the 'normal' the mean maximum urethral pressure in 71 controls between the ages 6-86 at a corrected age of 50 years was 60 cm H_2O with a standard deviation of 20 (23).

THE PLACE OF THE PROFILE

The evidence is that reliable and accurate information of urethral pressure can be obtained from a urethral pressure profile, but are the results of any value? The profile can be used as a clinical diagnostic investigation or for studying urethral function. As a diagnostic tool the profile has perhaps fallen short of its expectations. The need for a simple method of assessing urethral responses to electrical stimulation of the pelvic floor prompted the development of the Brown and Wickham technique, and it is well-suited to demonstrating such changes where the patient acts as his own control (23). Unfortunately increases in urethral pressure were not found to correlate well with the therapeutic response (8), although there is evidence that sustained profile changes do have prognostic significance (23).

In the investigation of incontience the differentiation of detrusor instability from defects of urethral closure remains a fundamental principle. Several studies have shown that in the condition of 'true stress incontinence' (28) urethral pressures are significantly lower than in normal people or those with detrusor incontinence (10, 11, 22, 23, 41). The diagnostic value of the profile in incontinence is blurred by the wide scatter of normal values, but a low value, relative to the patient's age, is strongly suggestive of sphincter deficiency, particularly if there is no detrusor instability. The ability of the profile to identify deficiencies of urethral closure is enhanced by Glen and Rowan's observation (19) that urethral pressure and functional length may deteriorate only when the bladder is filled to near capacity. They also feel that this is of prognostic significance with regard to treating incontinence electrically (18). There seems little doubt that detrusor instability and sphincter weakness may co-exist and in these circumstances the profile may provide the only objective evidence of the latter.

In addition to abnormalities of urethral pressure the configuration of the profile may show other characteristic changes such as increase or loss of the bladder neck component (1, 9, 23) or peaks due to strictures (5) or meatal stenosis (27).

The urethral pressure profile has been used to monitor changes in external sphincter activity following spinal trauma (40). With increasing time from the injury, and as reflex micturition develops, there is a progressive rise in profile pressures which may reach abnormally high values. Although the profile changes do not necessarily reflect detrusor/sphincter imbalance during micturition the investigation is valuable in the urological assessment of the patient with spinal injury.

Scott (36) has used the urethral pressure profile in the assessment and selection of patients for his artificial sphincter prosthesis. He suggests the profile offers a very useful way of checking the pressure exerted by the sphincter after insertion.

The urethral pressure profile is particularly suited to the study of urethral function. The components of urethral closure have been analysed in a number of elegant animal experiments by studying changes in the urethral profile in response to drug administration, nerve stimulation and vesical distension (15, 16, 29, 38, 39). The profile has been used in several studies in man which demonstrate the importance of the sympathetic component in urethral closure (6, 35, 44). Clinical studies have also shown significant changes in the urethral profile with the therapeutic administration of alpha-adrenergic blocking drugs (25).

CONCLUSIONS

The urethral pressure profile is a relatively simple method of obtaining objective information about urethral closure. The validity of the technique has now been established. Awareness of factors which may influence results, attention to technical details and an appreciation of the limitations of the profile should enhance the value of this investigation which has already contributed much to our understanding of normal and abnormal urethral function.

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