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The Measurement of Residual Urine by Means of Ultrasound (Sonocystography) in Neurogenic Bladder Disturbances

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Summary. The measurement of residual urine is important for bladder training in cases with neurogenic bladder dysfunction, especially in multiple sclerosis and in non-neurogenic retention. It is possible to measure the bladder volume precisely enough for even small amounts of residual urine by means of the ultrasound B-mode technique. A sector scan was used since with a linear array scan, the caudal part of the bladder cannot be visualized in female patients because of the pubic bone. The 144 volume data taken by ultrasound from normal persons and from patients without residual urine and the 19 measurements made in patients with residual urine more than 20 ml were compared with the urine volume determined by micturation or catheterization. The bladder volume was calculated from the maximum sagittal and transversal planes using an ellipsoid formula. The regression coefficient was 0.75. The correlation coefficient was 0.94 for bladder volumes between 0 and 200 ml. The standard deviation of the calculated residual urine as compared to the measured urine was 10.5 ml for a volume between 0 and 100 ml and 16.2 ml for a volume between 101 and 200 ml. Thus, ultrasound determination of residual urine may be recommended as a simple and reliable method when using a sector scan.

Key words: Residual urine – Ultrasound – Urinary bladder dysfunction – Multiple sclerosis – Rehabilitation.

Zusammenfassung. Harnwegsinfekte infolge von neurogenen Blasenstörungen sind eine häufige und schwerwiegende Komplikation zahlreicher Nervenkrankheiten, besonders der Multiplen Sklerose. Eine regelmäßige Restharnkontrolle bei diesen Patienten ist erforderlich, auch in der dezentralen

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symptomatischen Therapie und Rehabilitation. Es wird nachgewiesen, daß Restharnmessung mit Hilfe der Ultraschall-B-Mode-Technik möglich ist und auch beim Erwachsenen für kleine Blasenvolumina hinreichend exakte Meßwerte ergibt. Da sich mit dem Linear-Array-Scan vor allem bei weiblichen Patienten der untere (caudale) Blasenrand aufgrund des vorgelagerten Schambeins oft nicht darstellen läßt, wurde ein Sektor-Scan verwendet. 144 Ultraschallmessungen bei gesunden Versuchspersonen und Patienten ohne Restharn bei verschiedenen Blasenfüllungen sowie 19 Messungen bei Patienten mit Restharn über 20 ml wurden mit dem Miktionsvolumen bzw. mit der durch Katheter bestimmten Restharnmenge verglichen. Das Blasenvolumen wurde aus den sagittalen und transversalen Schnittbildern in Anlehnung an die Rotationsellipsoidformel berechnet. Der empirische Regressionskoeffizient betrug mit unserem Gerät 0,75 (im Gegensatz zum theoretischen 0,52 für das Rotationsellipsoid). Der Korrelationskoeffizient ist 0,94 für Blasenvolumina zwischen 0 und 200 ml. Die Standardabweichungen der errechneten Blasenvolumina von der gemessenen Harnmenge betrug 10,5 ml bei Harnvolumina zwischen 0 und 100 ml und 16,2 ml zwischen 101 und 200 ml.

Schlüsselwörter: Restharn – Ultraschall – Harnblasenstörungen – Multiple Sklerose – Rehabilitation.

Introduction

The treatment of neurogenic disturbances of the urinary bladder function by means of bladder training is usually successful, if the patient gets feedback from measurements of the residual urine. The goal is to reduce the residual urine to zero or at least below 60 ml. Although residual urine is usually measured by catheter, despite sterile precautions there is the risk of bladder infection inherent in any catheterization. Furthermore, catheterization is inconvenient, especially in male patients. There is even the risk of urethral lesions by the catheter, especially in elderly gentlemen or in cases with urethral stricture as a consequence of a previous indwelling catheter. (An indwelling catheter in the treatment of spinal cord injury or multiple sclerosis should never be recommended, although it is still widely advocated by textbooks or 'experts'.) The determination of residual urine with intravenous pyelography by X-rays cannot be applied in bladder training because of the risk connected with ionizing radiation.

Neurogenic disturbances of the urinary bladder function occur in congenital malformations or traumatic lesions of the spinal cord, after certain bilateral forebrain lesions, and especially in multiple sclerosis. Multiple sclerosis is the most frequent neurologic disease in nothern and middle Europe and North America. Since a causal treatment of multiple sclerosis does not yet exist, symptomatic treatment, rehabilitation, and prevention of secondary complications are most important (Kornhuber, 1977). Chronic infections of the urinary tract in multiple sclerosis as the result of neurogenic bladder dysfunction occur in one-third of the male MS patients and more than half of the female MS patients that are admitted to our hospital (Kornhuber and Jerusalem, 1968; Conrad and

Aschoff, 1972). If the residual urine was 80 ml or more, there was chronic cystitis in nearly all of the female patients and in two-thirds of the male patients.

A method of measuring residual urine that is free of risk and can easily be repeated is therefore important for symptomatic treatment of multiple sclerosis. Such a method would, of course, be valuable for the treatment of non-neurogenic bladder disturbances, too, such as hypertrophy of the prostate. Briefly, the easy and risk-free method is provided by ultrasound.

Methods

After several unsuccessful trials, we obtained good results with a mechanical ultrasound sector scan (Kretz Technik, Zipf, Austria) (Fig. 1). The model used had a frequency of 2.5 MHz and 5 rotating transducers operating over a sector of 60°. In comparison to the compound scan used in previous investigations, a real time scan with an image frequency of about 18 Hz had the advantage of better adjustment to the individual urinary bladder.

Our trials with linear-array scans that also operate in the real time mode and usually consist of 64 parallel crystals gave insufficient results. Especially in female patients, the lower wall of the bladder could often not be determined because of the os pubis which is almost impermeable for ultrasound.

The bladder volume was measured by a method similar to that of Pedersen et al. (1975). The ultrasound probe was applied just over the pubic bone on the midline. The maximum section area was determined in longitudinal and transversal directions (Fig. 2).

146 urine bladder volume measurements were taken with ultrasound in 4 male and 3 female normal adults who did not show any measurable residual urine. Thereafter, 38 multiple sclerosis patients were investigated, 19 of whom had residual urine. The urine volume was determined in the normal cases by micturation, and in the MS patients by catheterization. After micturation or catheterization, the absence of urine remaining in the bladder was always checked by ultrasound.

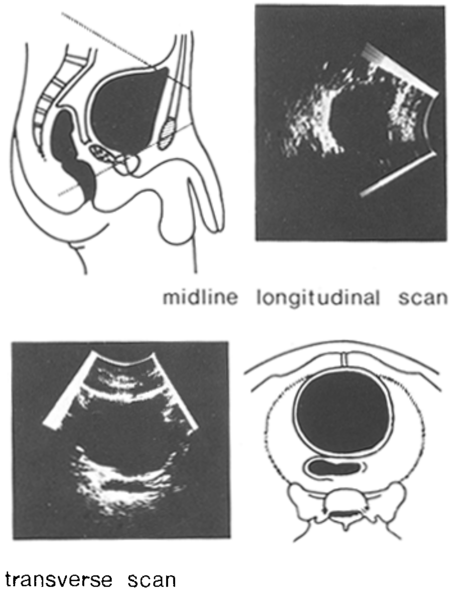

Fig. 1. Midline longitudinal and transverse ultrasound sections through the urinary bladder of a male patient (Volume ≈ 140 ml)

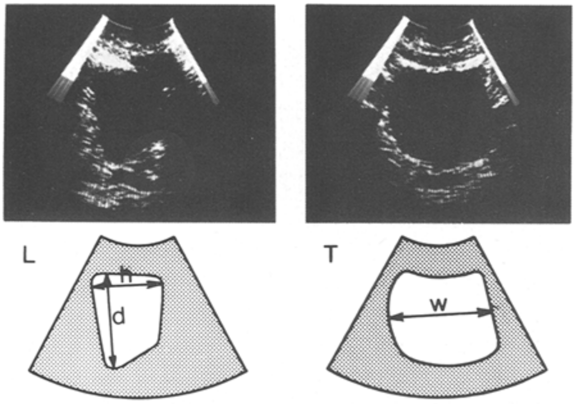

Fig. 2. Determination of bladder height *(h)*, depth *(d)* from the longitudinal, and of width *(w)* from the transversal ultrasound section

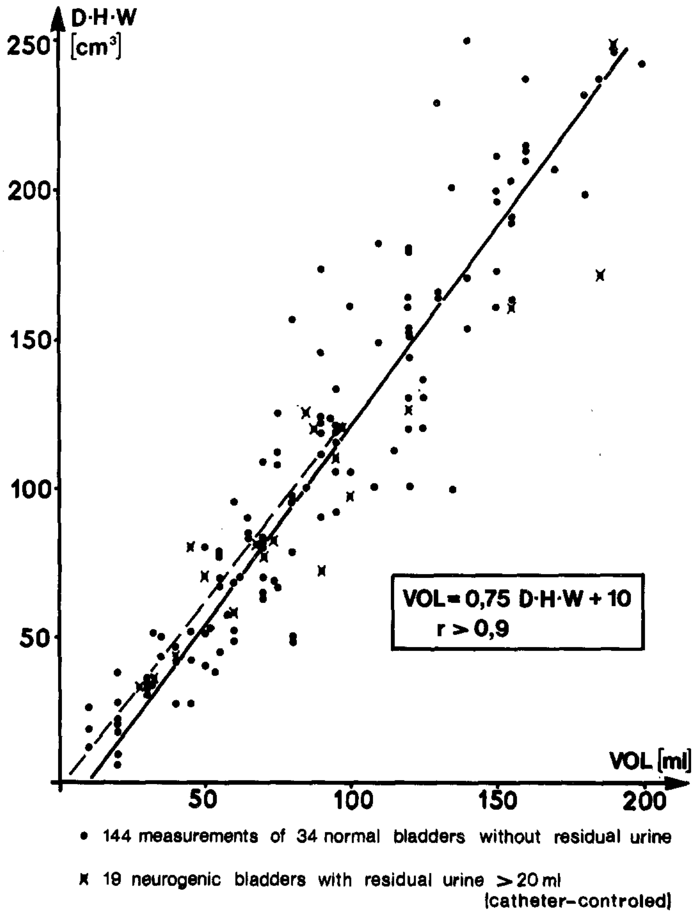

Fig. 3. Relationship between measured urine volume (abscissa) and ultrasound data (ordinate)

Results

From the total of 191 urinary volume measurements, only those were taken for the calculation of Fig. 3 in which the volume was less than 200 ml according to direct measurement by micturation or catheterization. These were 144 measurements from 34 persons without residual urine and 19 measurements from patients with residual urine of more than 20 ml. The regression line gave the equation:

$$\text{Volume} = 0.75\, D \cdot H \cdot W + 10$$

where D, H, and W are the depth, height, and width in cm; the volume results in ml. The correlation coefficient was 0.94 for a urinary bladder volume between 0 and 200 ml. The standard deviation was 10.5 ml for volumes between 0 and 100 ml, the standard error 1.1 ml. For volumes between 101 and 200 ml, the standard deviation was 16.2 ml, the standard error 2.1 ml. In all cases the urinary bladder could be distinguished from other tissue even if completely empty. For volumes from zero up to 100 ml the regression equation is:

$$\text{Volume} = 0.79 \cdot D \cdot H \cdot W + 2.$$

Discussion

From these results it is clear that with ultrasound sector scan techniques, even a small amount of residual urine in the adult patient can be determined with sufficient precision which makes the method useful for the control of bladder training. The real error is probably even smaller than the measured error, because the time interval between the ultrasound investigation and the determination of urine volume by micturation or catheterization was variable. If we consider that the secretion of urine by the kidneys may be as high as 10 ml/min, even an interval of a few minutes between the two measurements may result in a considerable discrepancy.

This positive result was due to the systematic variation of the techniques that ultimately led us to use a sector scan. Fortunately we started this investigation naively without knowledge of previous research that gave negative results from the practical point of view.

The failure of previous attempts to utilize ultrasound in the adult patient was probably due to inadequate techniques. The urinary bladder has an irregular shape, and its form changes depending on urine volume, intestinal volume, and sex. Because of these variations the A-scan techniques gave poor results (Holmes, 1967; West, 1967). With the two-dimensional compound scan technique the results were better but insufficient for residual urine less than 100 ml (Pedersen et al., 1975; Gockel and Ermert, 1977; McLean and Edell, 1978). However, the range below 100 ml is the important one for the control of bladder training. Only in children were satisfactory results obtained for residual urine below 100 ml (Weitzel and Blagojevic, 1978).

The use of the ellipsoid formula for the calculation of bladder volume gave results as good as the more difficult planimetric method. However, in contrast to the ellipsoid formula, volume $= 0.52 \cdot D \cdot H \cdot W$, the empirical factor from the regression line was 0.75. This may be because (1) the bladder is not an ideal ellipsoid form and (2) the bladder wall appears to be thicker than it really is. Perhaps this last factor varies when using different equipment. For other ultrasound devices, therefore, we recommend calibration.

For most observers determining residual urine visually with the ultrasound scope was practically as good as the exact calculation using the formula from the regression line. The measurement is simple and functions even in the hands of a nurse which is important for bladder training.

There is little doubt that the measurement of residual urine by ultrasound is less risky and simpler than other available methods. However, a sector scan costs about $25,000. This may be acceptable for hospitals, but it is too expensive for general use by small community nurses in decentralized rehabilitation. We are in the process of constructing a less expensive sector scan for this special purpose.

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