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Serial Residual Volumes in Men with Prostatic Hypertrophy

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Summary—Thirty men with prostatic hypertrophy were scanned on 3 occasions on the day before TURP. Five commonly used formulae to estimate residual urine were used. All of these methods are subject to large degrees of error; 66% of these patients had residual volumes that varied significantly on the same day.

We suggest that it is of no clinical value to perform a single residual urine measurement in patients with prostatic hypertrophy.

For some years it has been our impression that the results of residual volume estimations made by the Department of Radiology using ultrasound, in men with prostatism, did not correlate with the clinical picture. Often the residual volume measured by ultrasound seemed to be less than would be expected when palpating the abdomen. To determine whether this impression was correct we studied the residual volume of men with prostatism on 3 occasions during a single day. To our knowledge, no other study of serial residual volumes has been undertaken.

Patients and Methods

Thirty men who were due to undergo TURP were admitted to hospital 1 day earlier than usual. All were fully informed of the nature of the study and all gave their consent to be included. The mean age of the patients was 72.4 years (range 64–86).

Real-time ultrasound scanners were used (Siemens Sonoline SX) with 3.5 MHz hand-held probes. The patients were asked to drink steadily from the time of waking and when the urge to micturate was strong they were asked to void to what they thought was completion. They were then scanned. This process was repeated on two further occasions during the same day and the scans were timed at 09.00, 13.30 and 16.30 or as near to those times as possible.

After the third scan the patients resumed the normal pre-operative routine and all underwent TURP on the following day.

The post-micturition scans involved imaging the bladder in the transverse and sagittal planes with the probe placed a few cm above the pubis. Typical views of the bladder in these planes are shown in Figure 1. Figure 2 demonstrates this diagrammatically. The dimensions measured were:

H: Longest oblique dimension sagittally.
D^1: Antero-posterior dimension sagittally.
W: Width transversely.
D^2: Antero-posterior dimension transversely.
r: Radius in the transverse plane.

The transverse and sagittal areas were also measured. To calculate the volume of the bladder we used 5 formulae:

Hakenberg *et al.* (1983):
$0.625 \times H \times W \times (D^1 + D^2)/2$.
Poston *et al.* (1983):
$0.7 \times H \times W \times D^1$.
Hartnell *et al.* (1987):
$0.65 \times H \times W \times D^1$.
Rageth and Langer (1982):
Nomogram based upon transverse and sagittal areas.
Orgaz *et al.* (1981):
$12.56 \times H \times r$.

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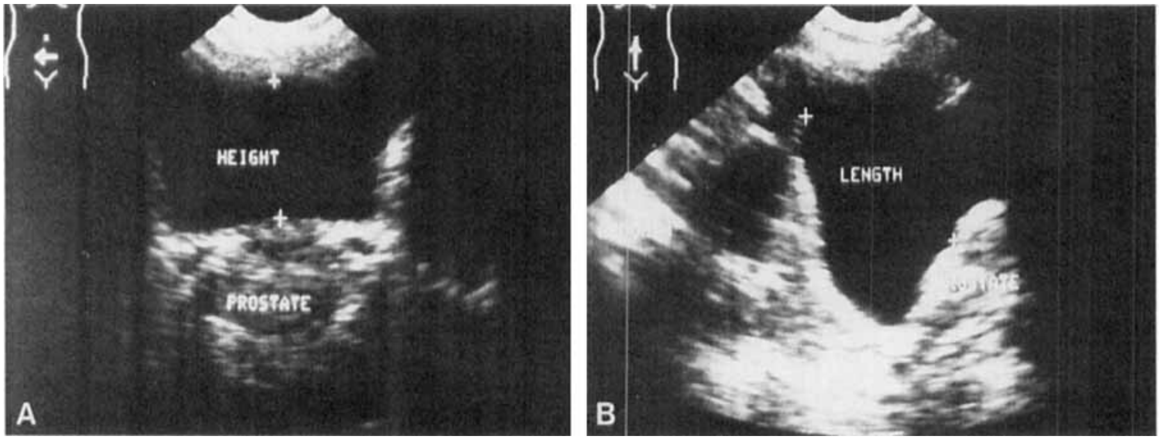

Fig. 1 Ultrasound scan showing transverse (A) and sagittal (B) views of the post-micturition bladder.

The first 3 formulae (Hakenberg *et al.* (1983), Poston *et al.* (1983) and Hartnell *et al.* (1987)) assume the shape of the post-micturition bladder to be a rectangular-based prism (Fig. 3). The volume of such a shape is (Height × Width × Depth) × 0.5. Based upon catheterisation volumes these authors altered the final coefficient to 0.625, 0.7 and 0.65 respectively. Rageth and Langer (1982) took the shape of the bladder to be an ellipsoid (Fig. 4) and devised a nomogram based upon the transverse and sagittal areas of the bladder to determine the residual volume.

Orgaz *et al.* (1981) used no known shape in their formula but adapted a series of geometrical variables to produce a formula with the smallest empirical error.

Because the post-micturition bladder does not conform to any geometrical shape perfectly, all of these formulae are subject to large degrees of error. Hartnell *et al.* (1987) calculated the error for the first 4 formulae and Orgaz *et al.* (1981) included the error of their test in their original report (Table 1).

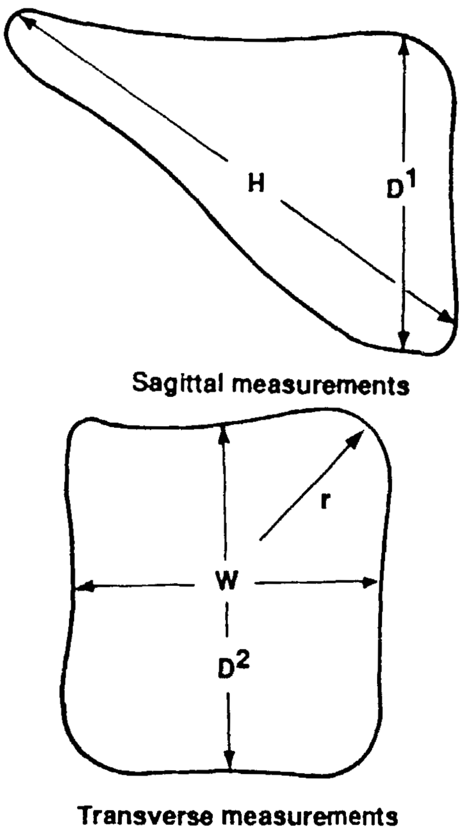

Fig. 2 Diagrammatic representation of ultrasound views of the post-micturition bladder.

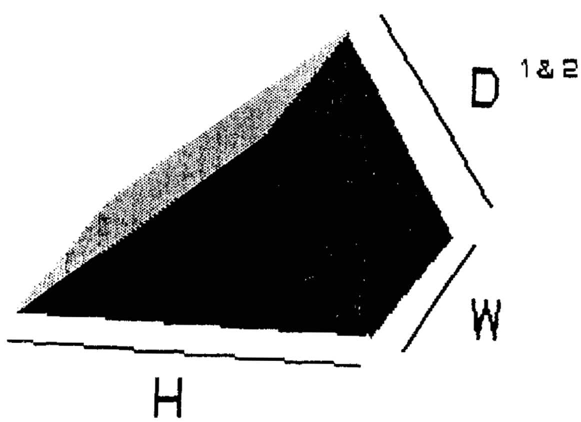

Fig. 3 Theoretical shape of the urinary bladder—rectangular-based prism.

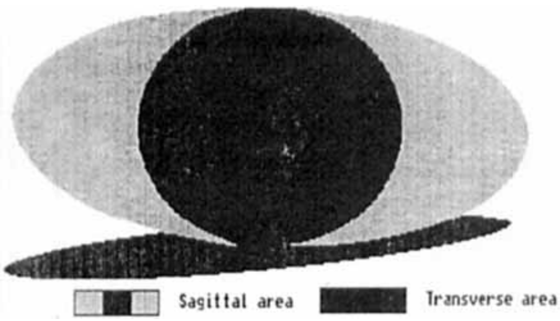

Fig. 4 Theoretical shape of the urinary bladder—ellipsoid

To validate our results statistically we applied 95% confidence limits (±1.96 × Standard Error) to each result. As Table 1 shows, the potential range of values for each volume measured is large because of the degrees of error inherent in each test. The possible outcomes for any one patient are therefore:

(1) All 3 scans show statistically similar volumes.
(2) Two scans show statistically similar volumes, but these are different from the third.
(3) All 3 scans show statistically different volumes.

We also calculated the concordance between all 5 formulae to demonstrate the interchangeability of the tests.

Table 1 Standard Errors for each Method of Calculating Bladder Volume and 95% Confidence Limits (±1.96 × SE)

Method	*Standard error (%)*	*±1.96 × SE*
Hakenberg *et al.* (1983)	17.5	34.3
Poston *et al.* (1983)	20.0	39.2
Hartnell *et al.* (1987)	17.0	33.3
Rageth and Langer (1982)	15.0	29.4
Orgaz *et al.* (1981)	12.9	25.5

Results

In all, 90 scans were performed. The 5 formulae chosen were applied to each of these scans, producing 450 results.

Table 2 shows the range of volumes for each formula. It also lists the mean, standard deviation and the proportion of patients with residual volumes lying between 100 and 600 ml. The minimum and maximum volumes in this Table do not apply to the same patient. All patients in this study had residual volumes on all 3 scans. The smallest volumes recorded are shown in Table 2. This patient had 3 scans with volumes all less than 100 ml. Only 1 other patient had 3 scans less than 100 ml, the majority being between 100 and 600 ml.

The maximum volume calculated is also shown in Table 2. This is the same patient as described in Table 3—a man in chronic retention who had great variation between scan volumes, but because of the degree of error involved in calculating residual volumes, the difference between the scans was not statistically significant. In contrast, the patient described in Table 4 shows that there can be large differences between scans that are significant—in

Table 2 Statistical Summary of Residual Volume Scans

Method	*Minimum volume (ml)*	*Maximum volume (ml)*	*Mean (ml)*	*SD (ml)*	*% scans 100–600 ml*
Hakenberg *et al.* (1983)	18	1098	253	216	75
Poston *et al.* (1983)	23	1647	282	272	75
Hartnell *et al.* (1987)	21	1532	261	249	77
Rageth and Langer (1982)	36	784	225	142	83
Orgaz *et al.* (1981)	46	998	324	182	89

Table 3 Patient Showing Maximum Variation between Scans with no Statistical Difference between Volumes, by Method

	Hakenberg et al. *(1983)*	*Poston* et al. *(1983)*	*Hartnell* et al. *(1987)*	*Rageth and Langer (1982)*	*Orgaz* et al. *(1981)*
Scan a (ml)	963	1023	951	455	607
Scan b (ml)	950	1337	1243	712	895
Scan c (ml)	1098	1647	1532	784	998
Difference (ml)	135	624	581	329	391

Table 4 Patient Showing Maximum Variation between Scans, by Method

	Hakenberg et al. *(1983)*	*Poston* et al. *(1983)*	*Hartnell* et al. *(1987)*	*Rageth and Langer (1982)*	*Orgaz* et al. *(1981)*
Scan a (ml)	879	1087	884	645	879
Scan b (ml)	523	601	530	410	534
Scan c (ml)	429	463	442	345	512
Difference (ml)	450	624	442	300	367

Table 5 Patient Showing Minimum Variation between Scans, by Method

	Hakenberg et al. *(1983)*	*Poston* et al. *(1983)*	*Hartnell* et al. *(1987)*	*Rageth and Langer (1982)*	*Orgaz* et al. *(1981)*
Scan a (ml)	345	398	370	233	496
Scan b (ml)	325	395	368	239	422
Scan c (ml)	323	406	377	261	405
Difference (ml)	22	11	9	29	91

Table 6 Summary of Results Showing the Proportion of Patients in each Group, by Method

Method	*No difference in volumes (%)*	*2 volumes different (%)*		*3 volumes different (%)*
Hakenberg *et al.* (1983)	10/30 (33.3)	18/30 (60.1)		2/30 (6.6)
Poston *et al.* (1983)	12/30 (40.0)	16/30 (53.4)		2/30 (6.6)
Hartnell *et al.* (1987)	10/30 (33.3)	17/30 (56.7)		3/30 (10.0)
Rageth and Langer (1982)	10/30 (33.3)	18/30 (60.1)		2/30 (6.6)
Orgaz *et al.* (1981)	9/30 (29.9)	18/30 (60.1)		3/30 (10.0)
Mean (%)	34	58	+	8
			66	

this case the first scan volume was more than double the final one.

Table 5 demonstrates that there can be remarkable consistency in residual volumes, even in a patient whose residual is as large, at times, as that shown in Table 4. As Table 6 illustrates, however, these are the minority of patients (34%).

It is evident that most patients fell into the group that had 2 scans that were statistically similar, but different from the third (58%) and only a small number had 3 scans that were all statistically different. Given the large degree of error inherent in each method of calculation, this is perhaps not a surprising result.

Discussion

Ultrasound, as a method of assessing bladder volume, has been used since Holmes first described it in 1967. Since then at least 14 studies have been published on methods of measuring residual volume using ultrasound. To our knowledge, no other study has measured serial residual volumes in men with prostatic hypertrophy. Hartnell *et al.* (1987) compared the accuracy of 3 methods, adapting the formula used by Poston *et al.* (1983) to give a smaller standard error, but examined only single scans.

It is recognised that ultrasound can be reasonably accurate in measuring volumes in normal subjects (Griffiths *et al.* 1986) but is less so in patients with bladder outflow obstruction (Hartnell *et al.* 1987), mainly due to the variation in bladder shape and the difficulty in applying geometrical formulae to the partially-filled bladder. In this study we used methods that assumed the bladder to be a rectangular-based prism and an ellipsoid, as well as the formula which is based upon no defined shape (Orgaz *et al.* 1981). We noted that all had large degrees of error as shown by Hartnell *et al.* (1987)

and the range of values possible for each scan when 95% confidence limits were applied varied from ±25.5% to ±39.2%.

Despite the different methods of calculation, the scans showed very similar distribution patterns and this is reflected in the concordance between the methods of 93.6%. It seems, therefore, that there is little to choose between these methods when calculating volumes. We suggest, however, that there is little point in accurately measuring a single residual volume in these patients as our results show that in 66% the residual volume varied significantly on the same day. Together with our radiologist colleagues, we discovered that not only is the actual measurement of post-micturition residual volumes time-consuming, but that it is often disruptive to an ultrasound list since it is usually impossible to continue with other scans until the patient with prostatism has emptied his bladder and has returned for the residual scan. This delay can sometimes be considerable. Indeed, in our area most radiologists no longer accurately measure the residual volume but estimate it as small, medium or large, which is quite adequate for urological purposes.

It is clear that accurate residual volume measurement is of no real importance in the investigation of patients with prostatic hypertrophy and is of equally little importance in planning the timing of prostatectomy. In addition, the fundamental inaccuracy of the methods of calculating residual volumes must severely prejudice the results of clinical trials that depend upon ultrasound to measure those volumes.

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References

Griffiths, C. J., Murray, A. and Ramsden, P. D. (1986). Accuracy and repeatability of bladder volume measurement using ultrasound imaging. *J. Urol.*, **136**, 808–812.

Hakenberg, O. W., Ryall, R. L., Langlois, S. L. *et al.* (1983). The estimation of bladder volume by sonocystography. *J. Urol.*, **130**, 249–251.

Hartnell, G. G., Kiely, E. A., Williams, G. *et al.* (1987). Real-time ultrasound measurement of bladder volume: a comparative study of three methods. *Br. J. Radiol.*, **60**, 1063–1065.

Holmes, J. H. (1967). Ultrasonic studies of the bladder. *J. Urol.*, **97**, 654–663.

Orgaz, R. E., Gomez, A. Z., Ramirez, C. T. *et al.* (1981). Applications of bladder ultrasonography. I. Bladder content and residue. *J. Urol.*, **125**, 174–176.

Poston, G. J., Joseph, A. E. A. and Riddle, P. R. (1983). The accuracy of ultrasound in the measurement of changes in bladder volume. *Br. J. Urol.*, **55**, 361–363.

Rageth, J. C. and Langer, K. (1982). Ultrasonic assessment of residual urine volume. *Urol. Res.*, **10**, 57–60.

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