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Ultrasonic Assessment of Residual Urine Volume

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Summary. A new method to assess residual urine volume using ultrasound has been developed. By measuring the areas of the bladder in both longitudinal and transverse directions the amount of residual urine volume can be estimated with a degree of accuracy comparable to the catheterisation method. A nomogram containing relevant urine volume determinations has been computed by applying the statistical method of multiple regression analysis in more than 200 cases studied. We find this nomogram to be easy to work with, and due to the advantages of ultrasonic assessment (e.g., there is no risk of infection, it is atraumatic, and it is quick), this approach may be recommended as a suitable method for routine practice in lieu of the catheterisation method.

Key words: Bladder volume determination, Ultrasound, Residual urine volume.

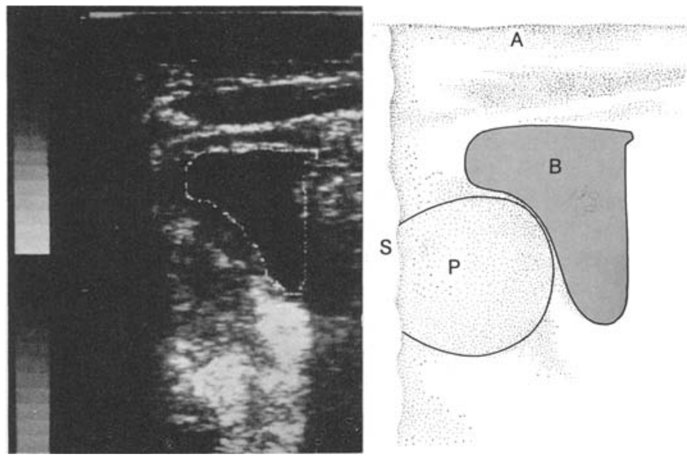

Fig. 1. Ultrasonic examination of urinary bladder. Prostatic hyperplasia. Sagittal section. (**S**: Shadow of pubic bone, **A**: Abdominal wall, **B**: Urinary bladder, **P**: Prostate)

Introduction

Until now is has not been possible to establish a non-invasive method for exact quantification of residual urine volume. The proposed radiological, nuclear medical, or biochemical methods have proved to be time-consuming, expensive, or inaccurate [1, 3].

Since 1967 [19] many authors have estimated residual urine volume by using ultrasound scans in various ways [5–7, 9, 11–17, 19] where the calculated estimations have been based, in most cases, on a modified geometrical formula of the rotation ellipsoid. Especially in the case of large residual urine volumes or in cases where the shape of the bladder differs from the expected normal form [8] as it does in some cases of prostatic hypertrophy (Fig. 1), the simple application of this formula can be misleading.

In order to obtain more accurate results, we measured the corresponding areas and *not* the various diameters. In a similar way Leucht [13] attempted to assess the residual volume in a patient who had had a previous hysterectomy and in a patient who had not. The results did not lead to the discovery of a useful method, although they demonstrated a new method of determining residual urine volume using ultrasound.

Methods and Results

Working on the principle of measuring the surface area, it is possible to derive the length of *all* diameters. We determined the maximum areas in longitudinal and transverse directions (Fig. 2) using a real-time scanner (Superscan, Kontron S.A., France) with the ability to measure the real area. On the basis of these two measurements we estimated the residual urine volume in more than 200 patients with various diseases. Next, we compared the assessed results with the urine volume quantification using the catheterisation method. As an appropriate statistical approach for analysing these data we chose the method of multiple regression analysis [18] and calculated a reliable table of urine volume assessments (Table 1) and a simple nomogram (Fig. 3).

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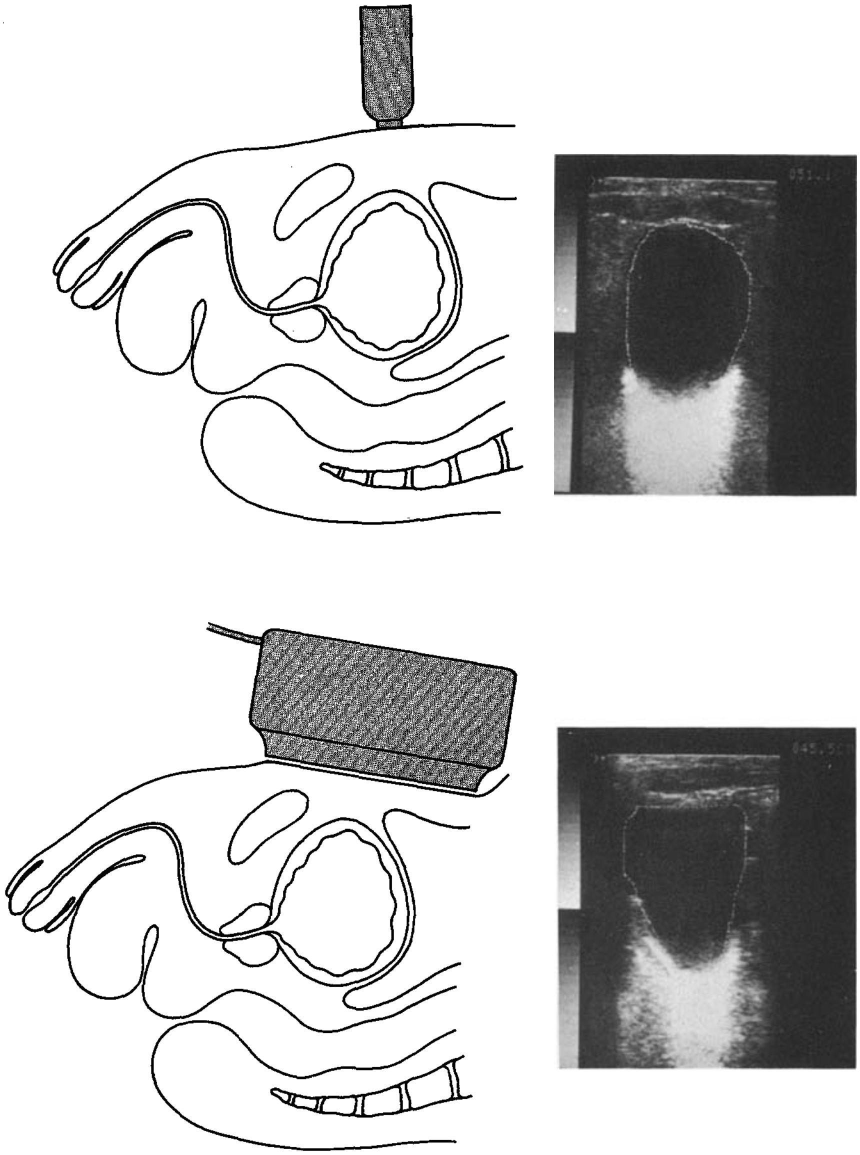

Fig. 2. Measurement of the greatest transverse (horizontal) area (*above*) and of the greatest longitudinal (sagittal) area (*below*)

Table 1. Table for estimation of residual urine volume

AL[a]	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80
AT[b]																
5	18	29	39	49	57	65	73	81	88	95	102	108	115	121	127	133
10	26	44	59	72	85	97	108	119	130	140	150	160	169	179	188	197
15	33	55	74	91	107	122	136	150	163	176	189	201	213	225	236	248
20	39	65	87	107	126	143	160	176	192	207	222	236	251	264	278	291
25	44	73	98	121	142	162	182	200	218	235	252	268	284	300	315	330
30	49	81	109	134	158	180	201	222	241	261	279	297	315	332	349	366
35	54	89	119	147	172	196	220	242	263	284	304	324	343	362	381	399
40	58	96	128	158	186	212	237	261	284	306	328	349	370	391	411	430
45	62	102	137	169	198	226	253	279	303	327	351	373	396	417	439	460
50	66	108	146	179	211	240	268	296	322	347	372	396	420	443	466	488
55	69	114	154	189	222	253	283	312	340	367	393	418	443	467	491	515
60	73	120	161	199	233	266	298	328	357	385	412	439	465	491	516	540
65	76	126	169	208	244	278	311	343	373	403	431	459	487	513	540	565
70	79	131	176	217	255	290	325	357	389	420	450	479	507	535	563	589
75	83	136	183	225	265	302	337	372	405	437	468	498	528	557	585	613
80	86	141	190	234	274	313	350	385	420	453	485	516	547	577	607	635

[a] Area longitudinal (sagittal) [b] Area transverse (horizontal)

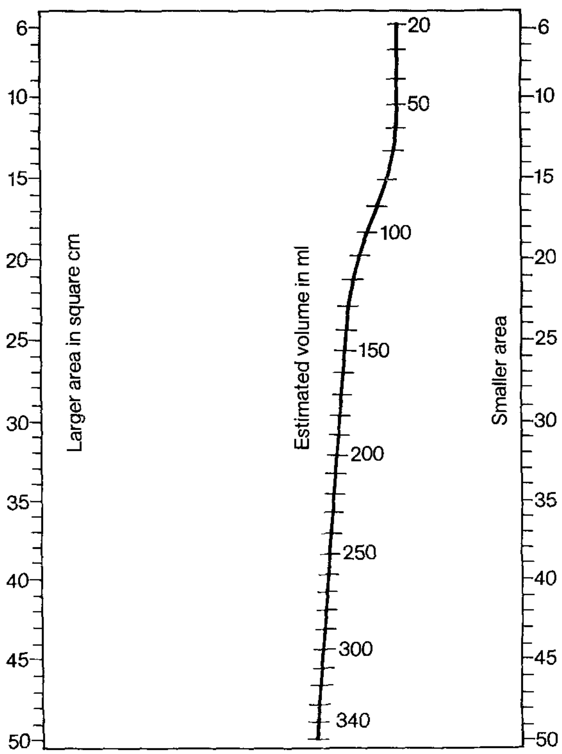

Fig. 3. Nomogram for estimation of residual urine volume

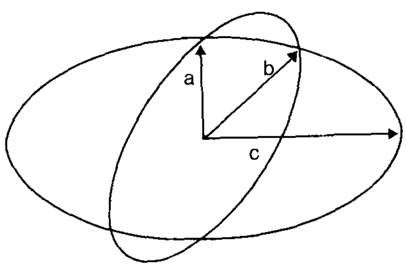

Fig. 4. An ellipsoid

Mathematical Approach

Based on the principles of multiple regression analysis [18], we developed a method to assess residual urine volume by the use of ultrasound scan. In contrast to methods where the respectice diameters have to be measured separately [2, 4, 5, 7, 10, 12, 14], we determined the area in both longitudinal and transverse directions (Fig. 2). The volume of the bladder was obtained in the following way.

At first the assumption was made that in the ideal case, the shape of the bladder was similar to that of an ellipsoid. In Fig. 4, such an ellipsoid is shown and the transverse and longitudinal surface areas were calculated by means of the formulae:

$$AT = \pi ab \qquad (1)$$

$$AL = \pi ac \qquad (2)$$

where the symbols a, b and c correspond to the various radii. The volume was calculated by applying the formula:

$$V = \frac{4}{3} \pi abc \qquad (3)$$

In several situations the assumption could be made that the shape of the bladder became similar to the shape of a rotation ellipsoid. If this supposition was correct we had:

$$b = a \qquad (4)$$

and therefore,

$$b = (AT/\pi)^{1/2} \qquad (5)$$

$$c = \frac{AL \cdot \sqrt{\pi}}{\pi \cdot \sqrt{AT}} \qquad (6)$$

Substituting (5) and (6) for b and c, we obtained:

$$V = \frac{4}{3} \cdot \frac{\sqrt{\pi}}{\pi} \cdot AL \cdot AT \qquad (7)$$

for (3).

Further data analysis could be made by applying the method of statistical regression analysis (in other words by approximating the residual urine volume in regard to the empirical by means of least square estimation). So we had:

$$V = \frac{4}{3} \frac{\sqrt{\pi}}{\pi} AL \cdot \sqrt{AT} \qquad (8)$$

or in the ideal case, transformed for the purpose of calculation:

$$\ln V = \ln \left(\frac{4}{3} \cdot \frac{\sqrt{\pi}}{\pi} \right) + \ln AL + \frac{1}{2} \ln AT \qquad (9)$$

For equation (9) we used the general form (10) for approximation:

$$\tilde{V} = \alpha + \beta \tilde{fl} + \gamma \tilde{ft} \qquad (10)$$

where it could be demonstrated that for assessing residual volume using the method we describe, the constant alpha and the regression coefficients beta and gamma had simply to be computed by means of multiple linear regression analysis. If these results were compared with the bladder volume quantification obtained by the method of catheterisation, the differences could be taken as the criterion for the reliability of our approach. We collected data from 206 patient studies, and the differences we found were less than 15% on average. Some greater discrepancies between the calculated volume and the actual volume determined by catheterisation existed in cases where the shape of the bladder differed greatly from a rotation ellipsoid (e.g., in patients with massive prostatic hypertrophy and in those with residual volumes above 400 ml).

We derived the following values for alpha, beta, and gamma:

$\alpha = 0.8304$ $\beta = 0.5625$ $\gamma = 0.7211$

The computed values are shown in Table 1 where AT and AL correspond to the empirically measured areas in both transverse and longitudinal directions. More easily residual urine volumes could be obtained by using the nomogram in Fig. 3. For practical purposes, it was important that the maximum longitudinal and transverse areas were always measured and that these data were used. The examples in Figs. 5 and 6 show that even when the shape of the bladder differed greatly from the shape of a rotation ellipsoid, a relatively exact measurement could be made using this method.

Discussion

Finding an accurate method of quantifying residual volume by an ultrasound technique may still be a problem in patients who have a massive infection of the bladder and where there is gross trabeculation or multiple diverticula.

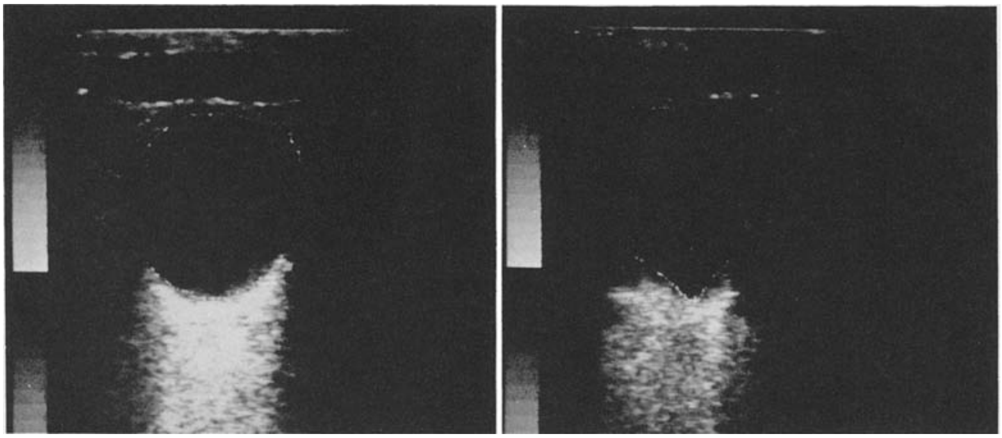

Fig. 5. Example 1. Area transverse: 29 cm, area longitudinal: 25 cm, estimated volume: 150 ml, by catheter: 150 ml

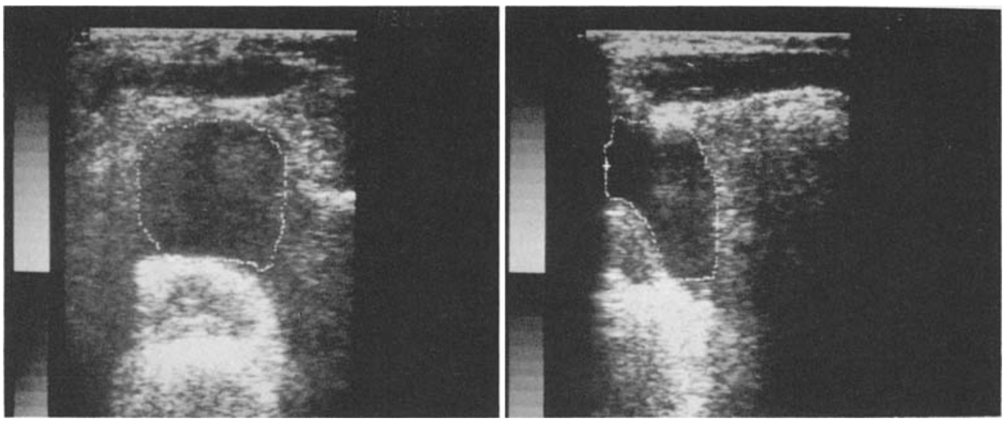

Fig. 6. Example 2: Area transverse: 21.8 cm, area longitudinal: 15.5 cm, estimated volume: 95 ml, by catheter: 100 ml

These factors diminish the accuracy of the determination of the area of the bladder wall.

Taking these limitations into account, the assessment of residual urine volume by ultrasound scan has several advantages: it is a non-invasive method and, therefore, atraumatic, with no risk of infection, and it requires only a few minutes to carry out. In our opinion, this approach can be recommended as a suitable method for routine clinical practice.

References

1. Axelrod DR (1966) Phenolsulfonphthalein excretion for estimating residual urine. Arch Intern Med 117:74–77
2. Bartels H (1981) Uro-Sonografie. Springer, Berlin, p 119
3. Bell R (1978) Measurement of residual urine volume without catheterization. J Tenn Med Assoc 71:520
4. Brunn J, Ruf G (1980) Sonografische Zystometrie. Dtsche Med Wochenschr 105:1501–1503
5. Corby VA, Heslop RA (1980) Bladder volume measurement by ultrasound. Radiography 46:187–189
6. Gockel HP, Ermert A (1977) Ultrasonic measurement of residual urine in neurogenic bladder. Utrasonics in clinical diagnosis. Wells P (ed). Churchill Livingstone, Edinburgh, p 148–151
7. Harrison NW, Parks C, Sherwood T (1976) Ultrasound assessment of residual urine in children. Br J Urol 47:805–814
8. Hinman F Jr, Cox CE (1967) Residual urine volume in normal male subjects. J Urol 97:641–645
9. Holmes JH (1967) Ultrasonic studies of the bladder. J Urol 97: 654
10. Kornhuber HH, Wider B, Christ K (1980) The measurement of residual urine by means of ultrasound (sonocystography) in neurogenic bladder disturbances. Arch Psychiatr Nervenkr 288:1–6
11. Le Duc A, de Trovar G, Robin P, Camey M (1979) L'exploration échotomographique du système collecteur pyelocaliciel et de la vessie. J Urol Nephrol (Paris) 85:737–745
12. McLean GK, Edell SL (1978) Determination of bladder volumes by gray scale ultrasonography. Radiology 128:181–182
13. Leucht W, Müller E, Heyes H, Lauritzen C (1980) Ultrasonografische Restharnbestimmung nach Hysterektomie. Geburtshilfe Frauenheilkd 40:1107–1111
14. Orgaz RE, Gomez AZ, Ramirez CT, Torres JLM (1981) Applications of bladder ultrasonography. Bladder content and residue. J Urol 125:174–176
15. Pedersen JF (1979) Bestemmelse af residualurin ved ultradyscanning. Ugeskr Laeger 141:649–650
16. Pedersen JF, Bartrum RJ, Grytter C (1975) Residual urine determination by ultrasonic scanning. Am J Roentgenol 125: 474–478
17. Weitzel D, Blagojevic S (1978) Zur Bedeutung sonografischer Restharnbestimmung im Kindesalter. In: Kratochwil A, Reinwald E (eds) Ultraschalldiagnostik. Thieme, Stuttgart, pp 187–188
18. Werner H, Schaback R (1972) Praktische Mathematik. Springer Berlin
19. West KA (1967) Sonocystography. A method for measuring residual urine. Scand J Urol Nephrol 1:68–70

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