CLINICAL UTILITY OF A PORTABLE ULTRASOUND SCANNER IN THE MEASUREMENT OF RESIDUAL URINE VOLUME

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ABSTRACT

Background: ***Post-voiding residual urine volume is an important investigation in the management of voiding dysfunction. Catheterisation is widely regarded as the "gold" standard method of measurement. We investigated the performance of a portable ultrasound scanner (Bladder Scan BVI-2500), as an alternative method of measurement.***

Methods: ***This study was prospective in nature. One hundred measurements of post-voiding residual urine volume by ultrasound were compared with measurements by catheterisation.***

Results: ***The mean absolute error of the scanner was 52 mL. For volumes below 200 mL and 100 mL, this was 36 mL and 24 mL respectively. A decision regarding whether to decompress the bladder by catheterisation would have also been correct in 86% to 89% of instances, depending on the cut-off value of the residual volume used. In other words, the ultrasound measurement would have been correct in 9 out of 10 clinical cases.***

Conclusion: ***We recommend the routine use of portable ultrasound scanners of similar accuracy in the measurement of post-voiding residual urine volume.***

Keywords: *residual urine, ultrasound, urinary retention, voiding dysfunction, urinary incontinence*

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INTRODUCTION

The post-voiding residual urine volume is the amount of urine left behind in the bladder after micturition. It is an important measurement for patients with urinary incontinence and other types of voiding dysfunction[1,2]. When large (that is, more than 100 mL), it is typically a sign of abnormal detrusor function[3,4], and values above 100 mL to 200 mL are indicative of the need for bladder decompression. This situation tends to occur more frequently with increasing age[5]. In clinical practice, large residual urine volumes with the clinical picture of urinary retention is a common problem in elderly patients.

"In-out" catheterisation of the bladder is widely regarded as the "gold" standard for the measurement of residual urine volume. However, catheterisation is beset with the risk of introducing infection. Studies have shown that the risk of acquiring bacteriuria after a single catheterisation varies anywhere between 2% and 15%[6]. In addition, catheterisation is also a time-consuming procedure and it can cause urethral trauma to the patient. It is no wonder that non-invasive methods of measuring residual urine volume have become an attractive option to both the practitioner as well as the patient.

In recent years, ultrasonography via the transabdominal, transrectal and transvaginal routes has been investigated and used in clinical practice[7]. Most of the studies done have investigated the use of the transabdominal route. Larger real-time scanners have been shown to be able to achieve reasonable accuracy in several studies[8]. Smaller, portable scanners achieved mean absolute errors in the residual urine volume assessment of the order of 44 to 56 mL[9,10]. The general opinion is that the technical accuracy of ultrasound scanners is satisfactory in the measurement of residual urine volume. The accuracy must be sufficient to guide the making of sound clinical decisions for the patient. This has already been demonstrated with larger real-time scanners[11]. With smaller, portable scanners, this has been less well investigated.

With these considerations, we sought to determine the accuracy of bedside ultrasonography in the measurement of residual urine volume, using the portable state-of-the-art Bladder Scan BVI-2500. Particular attention was given to volumes less than 200 mL - the range within which accuracy becomes of practical importance. The ability of the instrument to guide the making of clinical decisions in patients with voiding dysfunction was specifically studied.

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METHODS

A prospective study was carried out at a geriatric medicine department over a period of two months from April to June 1993. The patients were either inpatients of the department or outpatients attending a continence clinic run by the department. One hundred measurements of post-voiding residual urine volume were made by catheterisation in unselected patients. Prior to each catheterisation, the residual urine volume was measured using the Bladder Scan BVI-2500 (Diagnostic Ultrasound Corporation, Kirkland, Washington). This approximately 3 kg instrument consists of a box-shaped module with a hand-held scanning head. (Fig 1).

The areas of the largest transverse and saggital images of the bladder were obtained. The internal software of the instrument would then automatically calculate the volume of the bladder using a modification of the formula proposed by Griffiths[8]. Each single measurement took less than three minutes to perform. This was done by one and the same investigator. The catheterisation was performed by a doctor or continence nurse, who were blinded to the ultrasound results.

Fig 1 – Bladder Scan BVI-2500

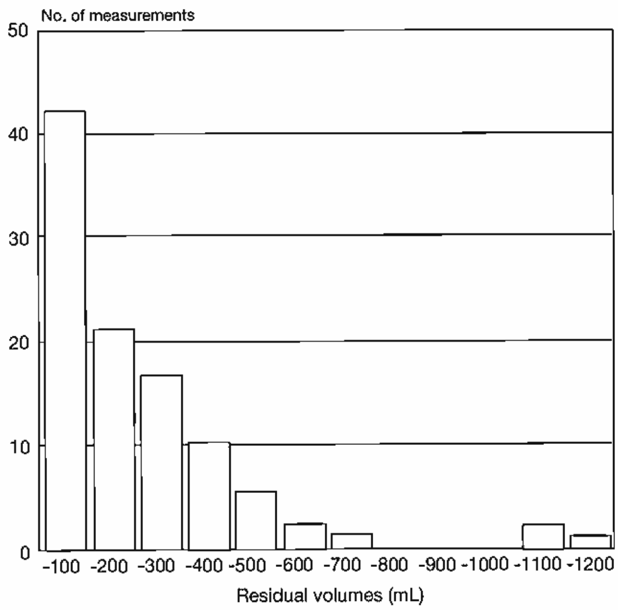
In the first 20 cases, a single ultrasound measurement was made. In the subsequent 80 cases, two ultrasound measurements were taken to investigate whether the accuracy of the ultrasound scanner could be further improved.

The ultrasound and catheterised volumes were compared and their extent of agreement was statistically analysed using calculations for 95% limits of agreement and *K* (kappa). The Pearson's correlation coefficient was also computed. However, as Bland and Altman[12] have pointed out, in the comparison of two methods measuring the same quantity, the statistical concept of "limits of agreement" would be more appropriate than the correlation coefficient. This is because the former measures how close the agreement is (which is important in this study), whereas the latter measures the degree of association (which is not relevant here). The Wilcoxon rank sum test was used to determine if there was any statistically significant difference in the error obtained between the first 25 and the last 25 measurements.

RESULTS

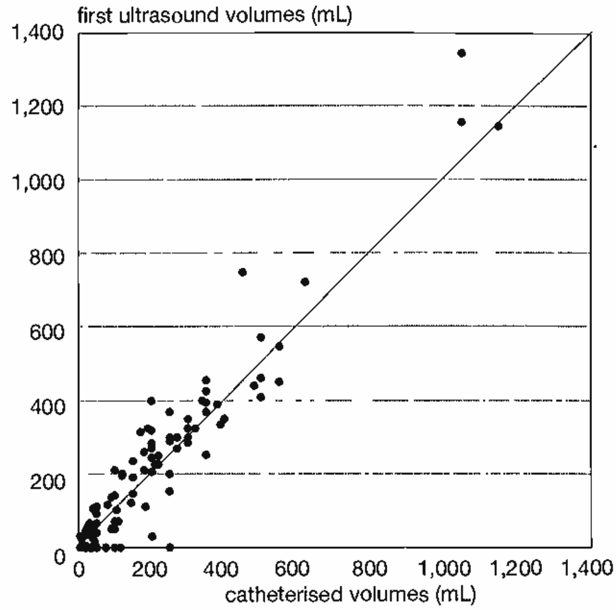
Forty-six (12 male and 34 female) patients were involved in this study. Their ages ranged from 40 to 95 years. They underwent a total of 100 catheterisations. The post-voiding residual urine volumes obtained by catheterisation ranged from 5 to 1150 mL. This is illustrated in Fig 2.

Fig 2 – Post-voiding residual urine volumes by catheterisation



The extent of errors incurred by the ultrasound method was assessed. Compared with the definitive catheterised residual urine measurements, the mean absolute error of the ultrasound method for the whole range of values was 52 mL (SD 77). For volumes less than 200 mL and 100 mL, it was 36 mL (SD 48) and 24 mL (SD 31) respectively. The correlation of the pairs of catheterised and ultrasound volumes is shown on a graph in Fig 3. The Pearson co-efficient of variation was 0.96. The 95% limits of agreement for the whole range of volumes, for volumes less than 200 mL and for volumes less than 100 mL were -144 to +164 mL, -97 to +95 mL and -64 to +60 mL respectively.

Fig 3 – Comparison of catheterised and ultrasound volumes



The ability of the ultrasound scanner to predict whether the residual urine volume was above specific critical volumes was assessed in the study population. Tables I and II show that the ultrasound scanner predicted correctly that the catheterised volumes were more than 100 mL and 200 mL or not in 89 out of 100 (89%) and 86 out of 100 (86%) cases respectively. The *K* value is a more precise way of estimating the strength of agreement between the two diagnostic methods. The *K* values obtained for the agreement on whether the residual urine volumes were more than 100mL and 200 mL were 0.78 and 0.76 respectively. Both values are in the range generally considered as being of good agreement.

For the 80 cases where two ultrasound measurements were made, the mean absolute error was +54 mL (SD 81) using the first measurement alone, and +55 mL (SD 86) when the average of the two measurements were taken. It is clear that there is no improvement in the errors obtained with the use of two measurements.

A graph showing the mean absolute error of the ultrasound measurements from the first to the one hundredth case in sequence is found in Fig 4. Using the Wilcoxon rank sum test to compare the error obtained in the first 25 measurements with that from the last 25 measurements, no statistically significant difference was obtained (z value of 1.25 and p value of 0.21). However, visual inspection of the graph in Fig 4 reveals an improving trend in the larger errors, with repeated use of the instrument.

DISCUSSION

In this study, the technical accuracy of the ultrasound

Table I – Comparison of catheterisation and ultrasound in determining whether residual urine volume is more than 100 mL or not

		ultrasound volumes	
		100 mL or less	more than 100 mL
catheterised volumes	100 mL or less	37	5
	more than 100 mL	6	52

Note: The shaded boxes indicate cases where there is agreement between the ultrasound and catheterisation (ie, 89/100 or 89%).

Table II – Comparison of catheterisation and ultrasound in determining whether residual urine volume is more than 200 mL or not

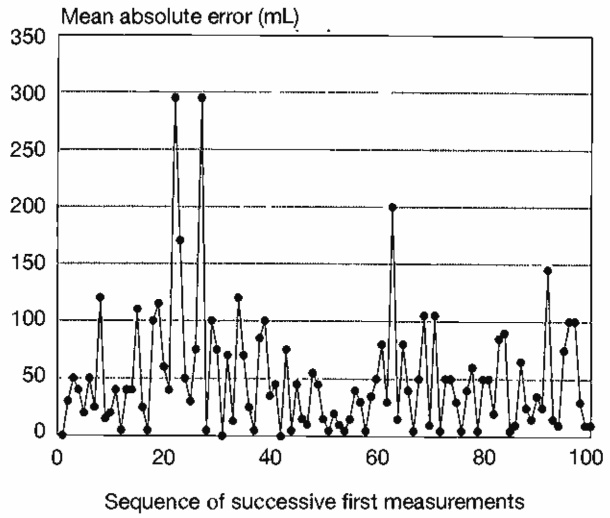
		ultrasound volumes	
		200 mL or less	more than 200 mL
catheterised volumes	200 mL or less	52	11
	more than 200 mL	3	34

Note: The shaded boxes indicate cases where there is agreement between the ultrasound and catheterisation (ie, 86/100 or 86%).

measurements of residual urine volume was comparable to that obtained in previous studies with small, portable ultrasound scanners. Cardenas[9] and Revord[10] obtained mean absolute errors of 56 mL and 44 mL respectively using the similar but older Bladder Scan BVI-2000. We obtained a mean absolute error of 52 mL.

For large residual urine volumes (eg more than 200 mL), small errors in measurement are not significant because they do not affect management decisions. However, it is within the range of residual urine volumes below 200 mL that accuracy is of greater importance. Many clinicians would decide on the need for decompression of the bladder by catheterisation depending on whether the residual urine volume is more than 100 mL to 200 mL. In addition, residual urine volumes exceeding 100 mL imply the presence of detrusor weakness. In these cases, drugs with anti-cholinergic properties need to be given with caution or avoided altogether, in view of the risk of precipitating urinary retention. Hence, residual urine volumes straddling these critical

Fig 4 – Error with successive first ultrasound measurements



volumes need to be measured with as much accuracy as possible. In this study, the mean absolute errors of the ultrasound measurements when compared with the catheterised volumes for volumes less than 200 mL and 100 mL was 42 mL and 26 mL respectively. We consider this degree of accuracy to be reasonable for routine clinical practice.

In this study, the ultrasound scanner was correct in determining whether the residual urine volumes were above or below 100 mL and 200 mL in about 9 out of every 10 instances. In other words, the decision to decompress the bladder by catheterisation, as well as identification of patients with detrusor weakness, who are at risk of developing urinary retention, would have been correct in about 9 of 10 instances. Using the portable ultrasound scanner, the risk of making incorrect decisions with harmful consequences would have been quite low.

Surprisingly, making two ultrasound measurements at the same sitting did not appear to improve the overall accuracy of the measurement significantly. As such, we do not have any data to support the practice of doing more than one ultrasound measurement routinely. However, repeating the ultrasound measurement at the same sitting may be useful if there is doubt as to the accuracy of the measurement, especially when scanning fat or distorted lower abdomens. In our study, the error obtained in this subset of patients tended to be larger, though the numbers were too small for any meaningful separate analysis.

We did not find any statistically significant improvement in the accuracy of ultrasound measurements with increasing experience over the first 100 measurements except perhaps with larger errors. This suggests that in general, the learning curve plateau very early in the use of this instrument.

The limitations of this study are two-fold. Firstly, the ultrasound volumes were compared with catheterised volumes in this study. A previous study elegantly demonstrated that catheterised volumes are themselves subject to a mean error of 76 mL when compared with fluoroscopy measurements[13], which are considered more accurate. However, catheterised volumes would normally be relied upon in clinical practice. As such, it would still be reasonable to compare any other method of residual urine measurement with the catheterised volumes, while bearing in mind the limitations of the latter. Secondly, only one investigator performed the ultrasound measurements. This may appear to reduce the extent to which we may extrapolate our results. However, a previous study with a similar ultrasound scanner with more than one investigator performing the measurements yielded very little inter-rater differences in measurement[14]. As such, it is likely that the results we obtained are representative of that which would be obtained in the hands of other interested clinicians.

CONCLUSION

Ultrasonography using portable scanners is a useful method of measuring post-voiding residual urine volume. It is non-invasive and thus, eliminates the risk of introducing infection and causing urethral trauma - problems which are associated with catheterisation. It can also be quickly and easily performed by the bedside. In addition, its technical accuracy is reasonable and it is reliable enough to guide management decisions which are based on the post-voiding residual urine volume. We recommend the routine use of portable ultrasound scanners of similar accuracy when measurement of post-voiding residual urine volume needs to be carried out.

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