Accuracy of Bladder Scanning in the Assessment of Postvoid Residual Volume

Ghadeer Al-Shaikh,[1] MBBS, FRCSC, Annick Larochelle,[2] MD, FRCSC, Craig E. Campbell,[1] MD, FRCSC, Joyce Schachter,[1] MD, FRCSC, Kevin Baker,[1] MD, FRCSC, Dante Pascali,[1] MD, FRCSC

[1]Department of Obstetrics and Gynecology, Division of Urogynecology and Pelvic Reconstructive Surgery, The Ottawa Hospital, Ottawa ON

[2]Department of Obstetrics and Gynecology, Hôpital Sainte-Justine, Montreal QC

Abstract

Objective: To compare the accuracy of the 3D portable ultrasound with catheterization in the assessment of postvoid residual (PVR) urine volume among women in the urogynaecology clinic.

Methods: A prospective study was performed, assessing 101 women. After the patient voided four ultrasound (US) assessments were carried out using the BladderScan BVI 3000; the patient was then catheterized. The reproducibility of the US measurements and the difference between the two methods were assessed using Bland and Altman plots. The strength of the relationship was measured by a simple Pearson correlation coefficient.

Results: The results showed that 3D scanner measurements were highly reproducible and were also found to correlate significantly with catheterized volume (r = 0.79, 95% CI 0.70–0.85, P < 0.001). The mean difference between the two methods was 12.9 mL (95% CI 5.5–20.2 mL, P < 0.001).

Conclusion: In determining PVR volumes, the portable ultrasound BladderScan BVI 3000 is an accurate alternative to bladder catheterization.

Résumé

Objectif : Comparer la précision de l'échographe portatif 3D à celle du cathétérisme en ce qui concerne l'évaluation du résidu vésical postmictionnel (RVP) chez les patientes d'une clinique d'urogynécologie.

Méthodes : Une étude prospective portant sur 101 femmes a été menée. À la suite de la miction, quatre échographies (EC) ont été menées au moyen du BladderScan BVI 3000; par la suite, on procédait au cathétérisme de la patiente. La reproductibilité des mesures EC et la différence entre les deux méthodes ont été évaluées au moyen de diagrammes de Bland-Altman. Le poids de la relation a été mesuré au moyen d'un simple coefficient de corrélation de Pearson.

Résultats : Les résultats indiquaient que les mesures de l'échographe 3D étaient grandement reproductibles; on a également constaté que ces résultats présentaient une corrélation significative avec le volume obtenu par cathétérisme (r = 0,79, IC à 95 %, 0,70–0,85, P < 0,001). La différence moyenne entre les deux méthodes était de 12,9 ml (IC à 95 %, 5,5–20,2 ml, P < 0,001).

Conclusion : Pour ce qui est de la détermination des volumes de RVP, l'échographe portatif BladderScan BVI 3000 constitue une solution de rechange précise au cathétérisme vésical.

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INTRODUCTION

Measurement of PVR urine volume is an important part of the evaluation of any urogynaecology patient. The PVR is defined as the volume of urine remaining in the bladder immediately after the completion of micturition. It can be measured by transurethral catheterization, by radiographic studies, or by ultrasound examination. A consistently high residual urine volume generally indicates increased outlet resistance, decreased bladder contractility, or a combination of the two. The Agency for Health Care Policy and Research in the United States recommends including a PVR measurement in the basic evaluation of all patients with urinary incontinence.[1] What constitutes an increased PVR volume is not universally established. Generally, women should void at least 80% of their total intravesical urine volume, or the PVR should be less than 100 mL.[2]

Women presenting to a urogynaecology clinic often complain of urinary incontinence, urgency, frequency, nocturia, dysuria, sensation of incomplete bladder emptying, genital prolapse or recurrent urinary infections. Others present for postoperative evaluation following a genital prolapse correction or an anti-incontinence procedure. Women wishing to be fitted with a pessary for conservative treatment of urinary incontinence or pelvic organ prolapse are also directed to the clinic. Each of these is an indication to proceed with a PVR measurement. An increased PVR may cause urinary incontinence, frequency, urgency, or recurrent urinary tract infections. Pelvic organ prolapse, anti-incontinence

procedures, and use of a pessary can be associated with increased PVR volume and consequently may lead to clinical problems such as recurrent UTI, bladder calculi, and chronic renal failure. Anticholinergic treatment for overactive bladder can also cause a significant increase in PVR and may lead to an aggravation of this problem.

At present, in-and-out bladder catheterization is recognized as the standard for an accurate PVR measurement.[3] However, this PVR assessment has limitations.[4] Even if urethral catheterization is well-tolerated, it is somewhat uncomfortable and unpleasant, and it increases the risk of urinary tract infection and urethral trauma. The incidence of UTI following a single in-and-out urethral catheterization in women has been estimated at between 1% and 20%.[5] A less invasive method of determining the PVR would be of great value. Abdominal palpation has been evaluated, but this option is not sensitive enough to identify significant degrees of urinary retention.[6] Radionuclide scans can be accurate but require expensive equipment.[7]

The use of ultrasound for evaluating bladder volume is quick, safe, non-invasive, painless, and well-accepted by patients. Several studies have used real-time ultrasonography as a possible alternative to assess the PVR transabdominally.[3,8,9] Two-dimensional US volume measurements seem to be accurate to within 20% for bladders with a regular shape, but become inaccurate for irregularly shaped bladders.[10] Two-dimensional US volume measurement also requires the use of formulas to calculate bladder volume. Depending on the volume of urine present, bladder shape may not always be regular.[10] Alternatively, 3D US is increasingly available for clinical use. This method adds to the non-invasive alternatives for PVR measurement. According to Riccabona et al.,[10] 3D ultrasound in vivo produces more accurate bladder volume measurements than 2D ultrasound. However, accessibility to the ultrasonographic equipment can be limited.

Portable US is a more appealing alternative to evaluate PVR volume. An additional important value of having such a scanner available includes decreasing the cost of materials and nursing time used for catheterization. Portable US contains software that automatically computes bladder volume. The first portable ultrasound units, BladderScan BVI 2000 and BVI 2500 use a two-step method: a sagittal scan and a transverse scan of the bladder. The BVI 3000 is considered to be a 3D US assessment and uses a one-step method.

Only two studies have examined the accuracy of the first bladder scanners (BVI 2000, BVI 2500, and BVI 2500+) among women attending an outpatient urodynamic assessment, and these showed that the scanners were reliable, non-invasive and fast in estimating postvoid residual among women with urinary incontinence.[11,12] Although these studies showed acceptable correlations between the portable ultrasound and bladder catheterization, they were not blinded and did not use complete statistical analysis.

Other authors have evaluated the validity of 3D portable ultrasound, using the BladderScan BVI 3000 to assess bladder volume. Two studies focused on the evaluation of bladder volume measurement in the postpartum period, and reached different conclusions.[13,14] The primary objective of the present study was to determine the accuracy of the 3D portable ultrasound BladderScan BVI 3000 in the assessment of the PVR volume compared with postvoid bladder catheterization among women presenting to a urogynaecology clinic. Both the intraobserver and interobserver reproducibility of the 3D ultrasound were tested. A secondary objective was to evaluate whether patient characteristics can influence the accuracy of 3D ultrasound assessment.

The study was performed using a blinded approach and accurate statistical analysis introduced by Bland and Altman.[15]

MATERIALS AND METHODS

Subjects were recruited directly from the urogynaecology clinic at the Riverside Campus, Ottawa Hospital. Every woman with an indication for a PVR evaluation in relation to her condition was asked to participate in the study. The indications for PVR measurement were urinary incontinence, genital prolapse, pessary fitting, recurrent UTI, overactive bladder (frequency, urgency, nocturia), interstitial cystitis, and postoperative follow-up for anti-incontinence and prolapse procedures. Written informed consent was obtained from all interested subjects.

Our review of published studies evaluating PVR assessment methods determined that these studies included between 50 and 100 subjects.[3,10–13] To assess power and sample size, the minimal clinically significant detectable difference was considered. An estimate of the variability of the difference between the two methods' estimates for a single

ABBREVIATIONS

2D	two dimensional
3D	three dimensional
PVR	postvoid residual
US	ultrasound
UTI	urinary tract infection

subject was also considered. The following formula was used to calculate the sample size:

$$n = \frac{(Z[1-\{\alpha / 2\}] + Z[1-\beta])^2}{ES}$$

Where ES = 30 / SD

SD = standard deviation

A difference in volume of 30 mL between the BladderScan BVI 3000 assessment and the volume with in-and-out urethral catheterization was considered to be clinically significant. The significance parameters $\alpha = 0.05$ and $\beta = 0.2$ represented the acceptable type I and type II errors.

To perform the sample size calculation, we estimated the standard deviation of the difference between the two measurement methods using the Altman and Bland statistical method. A similar study[13] had a mean difference of measurement between the BladderScan BVI 3000 and the in-and-out urethral catheterization of 42 mL, with a standard deviation of 71 mL. Using 71 mL as estimated standard deviation resulted in a required sample size of 45 patients. We ultimately recruited 101 patients.

We included in the study all patients presenting to the urogynaecology clinic at the Ottawa Hospital who required a PVR measurement. The urogynaecologic conditions were urinary incontinence, sensation of incomplete bladder emptying, overactive bladder (frequency, urgency, nocturia), recurrent UTI, interstitial cystitis, genital prolapse, pessary fitting and postoperative follow-up for any anti-incontinence or prolapse surgery.

The exclusion criteria were no indication for PVR measurement, patient refusal, the inability to obtain informed consent, PVR ≥ 1000 mL with urethral catheterization (because the BladderScan BVI 3000 provides an inaccurate estimate with volumes ≥ 1000 mL), and more than 10 minutes elapsed time between the BladderScan assessment and the urethral catheterization.

Initially each participant was interviewed and a urogynaecology history taken. Information about the women's age, height, weight, gravity, parity, menopausal status, use of hormone replacement therapy, prior hysterectomy, prolapse, bladder or anti-incontinence surgery was recorded. Information about the presence and grading of genital prolapse using the POPQ classification[16] was obtained by physical examination in every new patient or from chart review for known patients.

After voiding, a precatheterization ultrasound examination using the BladderScan BVI 3000 was performed to measure the PVR. This was carried out with the patient in the supine position. The scanner probe was placed on the patient's abdomen 4 cm above the pubic symphysis in the midline.

Table 1. Demographic and clinical characteristics of 101 women enrolled in the study

Characteristics	
Age, years	
Mean (SD)	57.5 (13.1)
Range	22–82
Gravidity	
Median (Q1, Q3)	2 (2,3)
Range	0–13
Parity	
Median (Q1, Q3)	2 (2,3)
Range	0–7
Height, cm	
Mean (SD)	161.2 (7.04)
Range	144–184.5
Weight, kg	
Mean (SD)	73.3 (13.9)
Range	44.5–115.4
BMI	
Mean (SD)	28.2 (5.4)
Range	17–42
Menopause, n (%)	66 (68.7)
Hormonal therapy, n (%)	14 (14.6)
Use of conjugated estrogen vaginal cream, n (%)	11 (11.5)
Hysterectomy, n (%)	31 (32.3)
Urinary incontinence surgery, n (%)	11 (11.5)
Pelvic organ prolapse quantification, n (%)	
0	19 (20)
1	26 (27)
2	43 (45)
3	5 (5)
4	3 (3)
Type of prolapse, n (%)	
Cystocele	40 (52)
Rectocele	37 (48)

Table 2. Measurements summary

Ultrasound results		Mean volume in mL (SD)	Range	Pearson intraobserver correlation coefficient	Pearson interobserver correlation coefficient
Operator 1	1st	38.8 (56.1)	(0–305)	0.97, $P < 0.001$	between two operators, 1st obs:
	2nd	40.4 (56.9)	(0–305)		0.82 , $P < 0.001$
Operator 2	1st	37.6 (49.3)	(0–244)	0.94 , $P < 0.001$	
	2nd	40.0 (54.4)	(0–333)		

The internal transducer in the scanner probe moves 3600 to scan the bladder in 12 planes and produces a three-dimensional image of the urinary bladder. On the basis of these images, the BladderScan automatically calculates the estimated bladder volume in mL and displays it on the screen. This measurement was executed twice by one operator and then twice by another operator to evaluate the intraobserver and interobserver reproducibility. The result of each measurement was blinded to the other operator. A third party collected the results to prevent any expectation bias. The two operators were urodynamic nurses who had been using the BladderScan for several months, following the Diagnostic Ultrasound Operator's Manual.

While the subject was supine, the urogynaecological nurse performed urethral catheterization to collect and determine the real volume of urine retained. This assessment was done using a 12-French Nelaton catheter, after cleansing the urethral meatus. The time elapsed between the bladder scan evaluation and the catheterization was less than 10 minutes.

Finally, a third ultrasound session was performed with the patient in the supine position, immediately after the catheterization, to determine the amount of urine that might have remained in the bladder following catheterization.

Initially, basic descriptive statistics were computed to characterize the sample. Intraobserver reproducibility was assessed by comparing pairs of measurements taken by the same operator, while interobserver reproducibility was assessed by comparing the measurements made by the two operators in the same subject. Bland and Altman plots were produced to examine the two levels of reproducibility. These figures show the difference between two measurements against their mean, together with a precision interval (mean difference ± 2SD). The Bland and Altman plot was used to evaluate the agreement between the two methods; a difference of more than 30 mL between the two methods was considered to be inaccurate. A paired sample *t* test was used to measure the difference between the two methods.

The validity of 3D-US for determining the PVR volume was evaluated using the first ultrasound performed by the first operator and the collected PVR value. Five patients having a post catheterization ultrasound estimate of > 80 mL were excluded from the analyses because of discordance between the ultrasound estimate and the actual PVR volume caused by the presence of large fibroids. The strength of the relationship between the 3D-US PVR measurement and the urethral catheterization assessment was determined by a simple Pearson correlation coefficient. A least squares linear-regression model was used for additional quantification of this association. This univariate regression was used to determine whether the difference between the two methods was related to any of the following patient characteristics: age, height, weight, BMI, prior hysterectomy, prior anti-incontinence procedure, genital prolapse ≥ POPQ stage II, post-catheterization ultrasound volume and actual catheterization PVR ≥ 100 mL. Multivariate regression was then carried out on the characteristics that were found to be statistically significant on univariate regression analysis.

RESULTS

The clinical characteristics of women in the study are shown in Table 1.

The measured volumes from the 3D scanner were highly reproducible. The Pearson correlation coefficient to assess the intraobserver reproducibility was 0.97 (95% CI 0.96–0.98). The Pearson correlation coefficient to assess the interobserver reproducibility was 0.82 (95% CI 0.78–0.89) (Table 2). The Bland-Altman plot confirmed the interobserver reproducibility (Figure 1).

The 3D ultrasound volume was significantly correlated with catheterized volume ($r = 0.789$; 95% CI 0.70–0.85, $P < 0.001$). Bland and Altman plots showed a greater variation between the two techniques than within them (Figure 2). Despite the significant correlation between the two methods, the average PVR values yielded by ultrasound were significantly smaller than those produced by catheterization

Figure 1. The Bland and Altman plot of the interobserver reproducibility

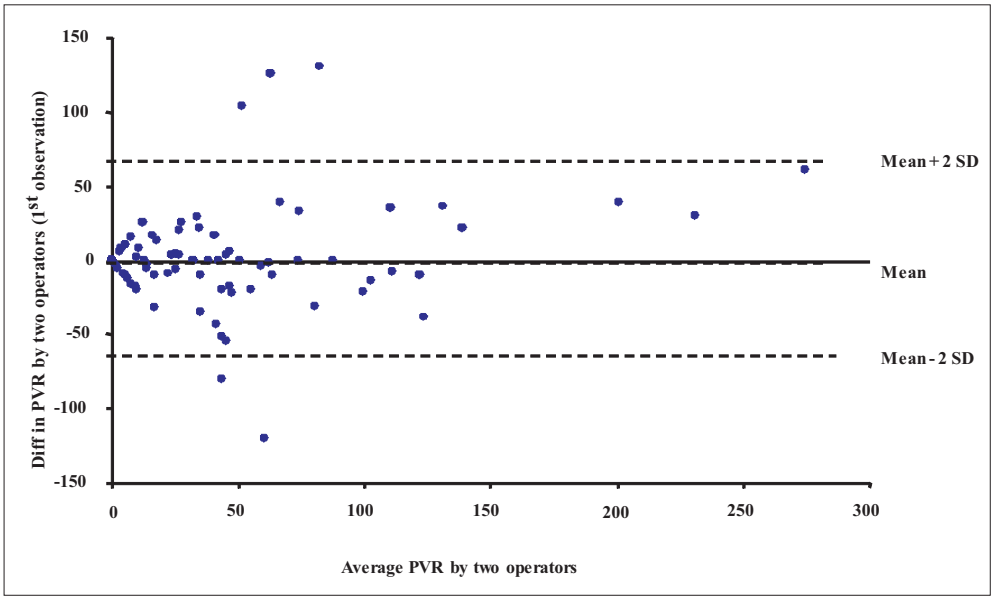
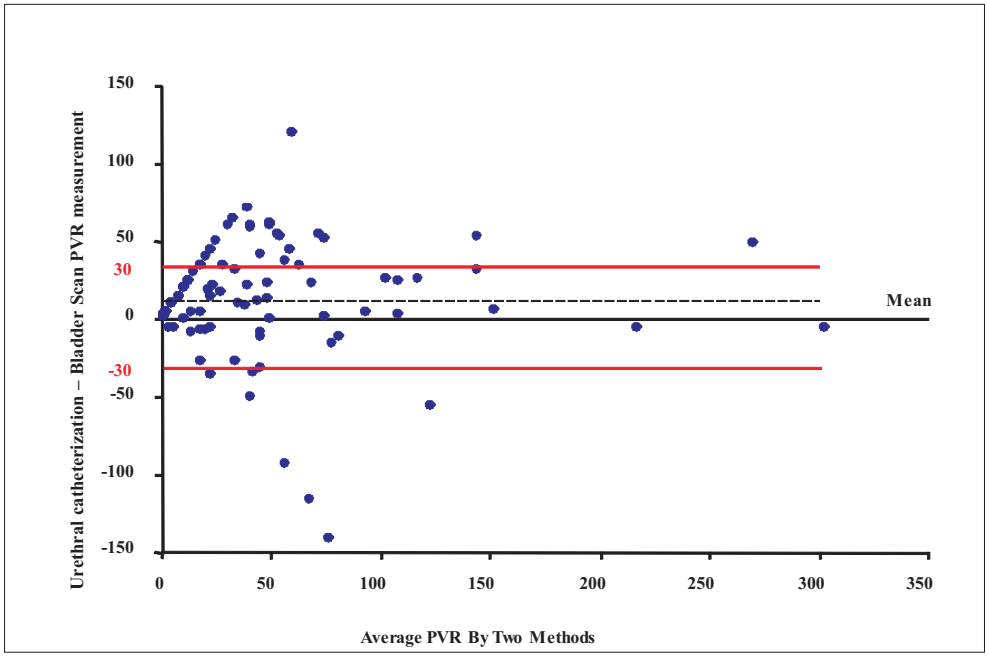


Figure 2. The Bland and Altman plot of the variation between the two techniques



(mean difference 12.9 mL; 95% CI 5.5–20.2 mL, $P < 0.001$). More specifically, the 3D-US tended to underestimate the post-void residual volume by a mean of 12.9 mL.

A difference of 30 mL between the two methods was considered clinically significant. Based on this, 62 (64.6%) measurements were considered to be acceptable, 8 (8.3%) observations were overestimated by more than 30 mL, and 26 (27.1%) observations were underestimated by more than 30 mL with the 3D ultrasound method compared with catheterization.

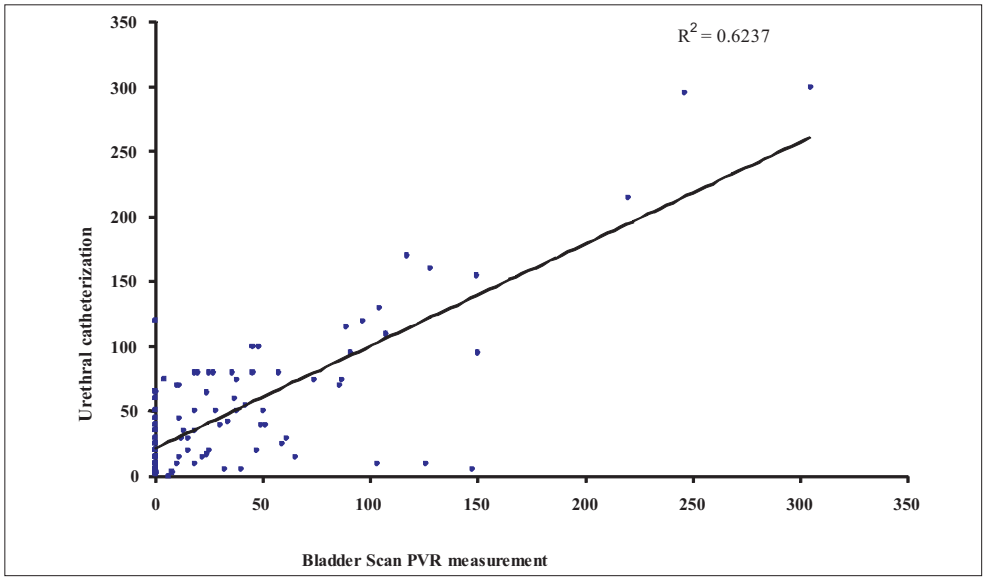
The linear regression analysis confirmed the correlation between the two techniques ($R^2 = 0.62$). The slope of the regression line was estimated at 0.79, with an intercept at 21.13, illustrating the tendency for the ultrasound scan to underestimate the volume of PVR (Figure 3).

The difference between the two methods was not significantly correlated with age ($P = 0.73$), height ($P = 0.19$), or weight ($P = 0.35$). T tests did not show any difference between obese (BMI > 30) and non-obese (BMI ≤ 30) patients when comparing the mean differences between the

Table 3. Multivariate model

Variable	Parameter estimate	Standard error	*t* value	Pr > |t|
PVR volume (> 100 mL vs. < 100 mL)	20.053	10.47	1.92	0.0585
Hysterectomy (yes vs. no)	4.968	8.03	0.62	0.5375
Post-catheterization	–0.751	0.31	–2.44	0.0164

Figure 3. The linear regression analysis of the correlation between the two techniques



two methods (P = 0.39). There was also no relationship with genital prolapse (P = 0.7).

The difference between ultrasound and catheterization was significantly related to hysterectomy. The mean difference (catheterization volume minus ultrasound volume) was 22.2 mL (95% CI 13.1, 31.2) in the hysterectomy group, compared with 8.4 mL (95% CI –1.5, 18.4) in the group without hysterectomy (P = 0.042). The difference between the two techniques was inversely associated with the post-catheterization ultrasound volume (correlation coefficient: –0.29, P = 0.004). In patients with a post-catheterization ultrasound volume of 0 mL (70% of total), the mean difference between the two methods was 17.2 mL (95% CI 9.0, 25.5) but in patients with a post-catheterization US volume > 0 mL, the mean difference was 1.1 mL (95% CI –14.6, 16.9, P = 0.053). There was also a significant relationship between the difference in measured volume between both techniques and the actual PVR value determined by catheterization; the mean difference was 9.6 mL (95% CI 1.8, 17.4) for cases with PVR < 100 mL and 33.5 mL (95% CI 13.1, 54) for cases with PVR ≥ 100 mL. The difference between the catheter and the US volumes in patients with PVR ≥ 100 mL ranged from 3 mL to 59 mL.

The multivariate regression model was used for the following statistically significant univariate characteristics: hysterectomy, post-catheterization ultrasound equal to 0 and actual catheterization PVR ≥ 100 mL. This analysis showed significant results for post- catheterization ultrasound equal to 0 mL (P = 0.016) (Table 3).

DISCUSSION

The results of this study show that use of urethral catheterization and of ultrasound bladder scanning for determining the PVR volume were significantly correlated (r = 0.79; 95% CI 0.70–0.85, P < 0.001). Despite the significant correlation between the two methods, the 3D-US tended to underestimate PVR volume by a mean of 12.9 mL (95% CI 5.5–20.2, P < 0.001). It is possible that the

difference between the two methods was due to urine production in the time elapsed between the ultrasound and the actual catheterization (diuresis factor), as our patients were instructed to drink two glasses of water one hour prior to their visit to the clinic. However, in 8.3% of the cases ultrasound measurement overestimated the PVR volumes. This could be due to misidentification of the bladder, or distended bowel interfering with the signal. Moreover, although the difference between ultrasound measurement and catheterization of 12.9 mL is statistically significant, it is not clinically significant. A difference of less than 30 mL was arbitrarily not considered clinically meaningful by our research team, and because the confidence interval for the mean difference does not include values above 30 mL, the difference between both methods is not meaningful in a clinical setting.

Various factors that might be associated with the difference between PVR values obtained by ultrasound and catheterization were assessed. Our results did not show that pelvic organ prolapse is a factor in the accuracy of the bladder scanner; only a small percentage of patients had stage 3 or 4 prolapse, and it remains uncertain whether or not US measurement is accurate in women with significant prolapse. As discussed, the multivariate regression model showed that a post-catheterization ultrasound value equal to 0 mL ($P = 0.016$) (Table 3) was the only significant factor in determining a difference between the measurements by ultrasound and catheterization. Nevertheless, this finding would have minimal clinical importance because ultrasound would not normally be carried out post catheterization.

Because measurements in this study were performed by urogynaecology nurses, and because the BladderScan BVI 3000 is easy to use, our results are presumably generalizable to the "casual" measurer of PVR volume, so long as they are appropriately instructed in performing the measurement.

CONCLUSION

For determining PVR volumes, the portable ultrasound BladderScan BVI 3000 is an accurate alternative to the standard measurement by in-and-out bladder catheterization. The BladderScan BVI 3000 is a useful instrument for measuring PVR volumes in a busy urogynaecology clinic.

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REFERENCES

1. Fantl JA, Kaschak Newman D, Colling J, DeLancey JOL, Keeys C, Loughery R, et al. Urinary Incontinence in adults: acute and chronic management. Clinical Practice Guideline, 1996; No. 2: Agency for Health Care Policy and Research Publication No. 96–0682.
2. Walters MD, Karram MM. Urogynecology and reconstructive pelvic surgery. 2nd ed. 1999:70.
3. Mainprize TC, Drutz HP. Accuracy of total bladder volume and residual urine measurements: comparison between real-time ultrasonography and catheterization. Am J Obstet Gynecol 1989;160:1013–6.
4. Stoller ML, Millard RJ. The accuracy of a catheterization residual urine. J Urol 1989; 141(1):15–6.
5. Stamey TA, Pfau A. Urinary Infections: a selective review and some observations. Calif Med 1970;113(6):16–35.
6. Nygaard IE. Postvoid residual volume cannot be accurately estimated by bimanual examination. Int Urogynecol J Pelvic Floor Dysfunct 1996;7(2):74–6.
7. Groshar D, Embon OM, Sazbon A comparison of a radionuclide method and catheterization for the measurement of residual volume of urine in the bladder. Clin Nucl Med 1987;12(5):363–4.
8. Griffiths CJ, Murray A, Ramsden PD. Accuracy and repeatability of bladder volume measurement using ultrasonic imaging. J Urol 1986;136(4):808–12.
9. Rageth JC, Langer K Ultrasonic assessment of residual urine volume. Urol Res 1982; 10(2):57–60.
10. Riccabona M, Nelson TR, Pretorius DH, Davidson TE. In vivo three-dimensional sonographic measurement of organ volume: validation in the urinary bladder. J Ultrasound Med 1996;15(9):627–32.
11. Goode PS, Locher JL, Bryant RL, Burgio KL. Measurement of postvoid residual urine with portable transabdominal bladder ultrasound scanner and urethral catheterization. Int Urogynecol J Pelvic Floor Dysfunct 2000;11(5):296–300.
12. Barrington J, Bowen-Simpkins P. A comparison between portable ultrasound and urethral catheterization in the measurement of female bladder volume. J Obst Gynaecol. 1996;16:50–1.
13. Demaria F, Amar N, Biau D, Fritle X, Porcher R, Amarenco G, et al. Prospective 3D ultrasonographic evaluation of immediate postpartum urine retention volume in 100 women who delivered vaginally. Int Urogynecol J 2004;15:281–5.
14. Pallis LM, Wilson M. Ultrasound assessment of bladder volume: is it valid after delivery? Aust N Z J Obs Gynaecol 2003;43(6):453–6.
15. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1986;1:307–10.
16. Bump RC, Mattiasson A, Bø K, Brubaker LP, DeLancey JO, Klarskov P, et al. The standardization of terminology of female pelvic organ prolapse and pelvic floor dysfunction. Am J Obstet Gynecol 1996;175(1):10–7.