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Accuracy of Post-Void Residual Urine Volume Measurement Using a Portable Ultrasound Bladder Scanner With Real-Time Pre-Scan Imaging

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Aims: To evaluate whether the bladder scanner with real-time pre-scan imaging (RPI) is superior to the conventional bladder scanner in measuring post-void residual urine (PVR) volume. **Methods:** Sixty-seven patients with voiding dysfunction were subjected to PVR volume measurements. The PVR volume was measured three times by two experienced examiners using bladder scanners with (BioCon-500, Mcube Technology, Seoul, Korea) or without (BVI-3000 BladderScan, Verathon, WA) RPI. Immediately after the procedure, urethral catheterization was performed to obtain true volume. The accuracy and variability of measurements were compared between the two devices and correlation coefficients were obtained. **Results:** The Pearson correlation coefficients between the PVR volume measured by each device and the true volume were 0.932 for the bladder scanner without RPI and 0.950 for the bladder scanner with RPI. The bladder scanner without RPI tended to overestimate the true volume in moderate volume ranges (>100 ml) by a mean percentage of differences of volume (PDV) of 16.3%, while the bladder scanner with RPI underestimated the true volume in the whole volume range by a mean PDV of −14.1% ($P < 0.001$). Repeated measures ANOVA showed no significant interobserver variability ($P = 0.977$ for the bladder scanner without RPI and $P = 0.853$ for the bladder scanner with RPI) or intraobserver variability ($P = 0.660$ for the bladder scanner without RPI and $P = 0.271$ for the bladder scanner with RPI). **Conclusions:** Our results showed that exact pointing to the bladder prior to actual measurement of bladder volume with RPI seems to reduce the variability of the measured values. *Neurourol. Urodynam. 30:335–338, 2011.* © 2010 Wiley-Liss, Inc.

Key words: bladder scanner; post-void residual urine; real-time pre-scan imaging

INTRODUCTION

Measurement of post-void residual urine (PVR) volume is an important component in the assessment of patients with voiding dysfunction. The adoption of portable ultrasound bladder scanners as a noninvasive form of measurement has been widely accepted. It has been demonstrated that the accuracy of these devices is acceptable enough for clinical use.[1] Even more recently, in an aim to improve accuracy, a portable ultrasound bladder scanner equipped with an additional real-time pre-scan imaging (RPI) has been introduced. It theoretically seems to be able to enhance accuracy, as it can provide examiners with prelocalization of the central target point as well as information on the shape of the bladder prior to actual scanning. However, although there are potential advantages of a portable ultrasound bladder scanner with RPI, its performance compared to the conventional blind portable ultrasound bladder scanner has not been studied. In the present study, we investigated whether the device with RPI is superior to the conventional blind portable ultrasound bladder scanner in measuring PVR.

MATERIALS AND METHODS

Patients

A total of 67 patients (28 men and 39 women) were prospectively included in this study from September 2007 to March 2008. All the patients attended an outpatient clinic for the evaluation of voiding dysfunction. Exclusion criteria included a history of bladder surgery, age younger than 18 years, or pregnancy. The procedure was approved by the Institutional Review Board of Human Research of Seoul National University Hospital, and an informed consent was obtained from all patients before their entry into the study.

Study Design

After voiding, the patients were asked to be in the supine position. The PVR volume was measured using both the portable 12 frame B-mode sector-probe ultrasound bladder scanner with (BioCon-500, Mcube Technology, Seoul, Korea) (Fig. 1) or without (BVI-3000 BladderScan, Verathon, WA) RPI. The bladder scanner with RPI (frequency 2.8 MHz, 120° scan angle, size 240 mm × 375 mm × 116 mm, weight 2.86 kg) uses a 2.8 MHz volumetric probe with a transducer that is steered to collect 12 cross-sectional images (15° apart) in one step and provides a coronal bladder outline on a monitor in the shape of a target with cross-hairs. The probe was centered to view the bladder in its largest cross-section. While scanning, it continuously displayed the horizontal plane image. On pressing the probe, the picture froze and the bladder volume was calculated automatically. For the bladder scanner without RPI (frequency 2.0 MHz, 120° scan angle, size 230 mm × 320 mm × 70 mm, weight 2.25 kg), after selecting the patient gender, the probe was fixed at the suprapubic area and activated. Several measurements were taken to ensure the maximum accuracy until the largest volume was obtained according to the manufacturer's protocol.

Conflict of interest: none.
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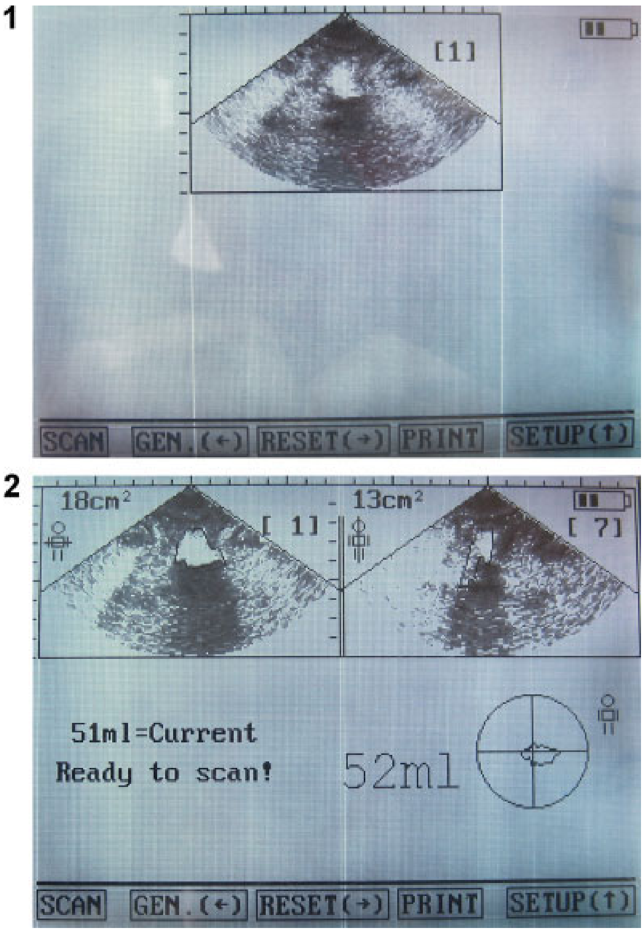

Fig. 1. Portable ultrasound bladder scanner with real-time pre-scan imaging (transverse plane). (**1**) Scanning in progress. (**2**) Completion of scanning.

Using each device, each measurement was done three times by two experienced independent examiners (A and B) randomly, which meant a total of 12 measurements was done in a single patient. The time taken to complete measurement was recorded. Immediately after the procedure, urethral catheterization was performed to obtain the true volume of the bladder.

Statistical Analysis

The accuracy of the two devices was evaluated by the percentage of differences of volume (PDV) calculated by dividing the measured volume by the true volume.[1] A paired *t*-test was used to determine whether the differences in the PVR volume measured by each device and the time taken for each measurement were statistically significant. Repeated measures ANOVA was used to compare both the PVR volume measurement of the two independent examiners and the PVR volume measurements of the same examiners. The Pearson correlation coefficients (r) were calculated to identify potential correlations among the true volume and the PVR volume measured by each device. Fisher's r-to-z transformation was used to test for significant differences between r values of both groups. A value of $P < 0.05$ was considered statistically significant.

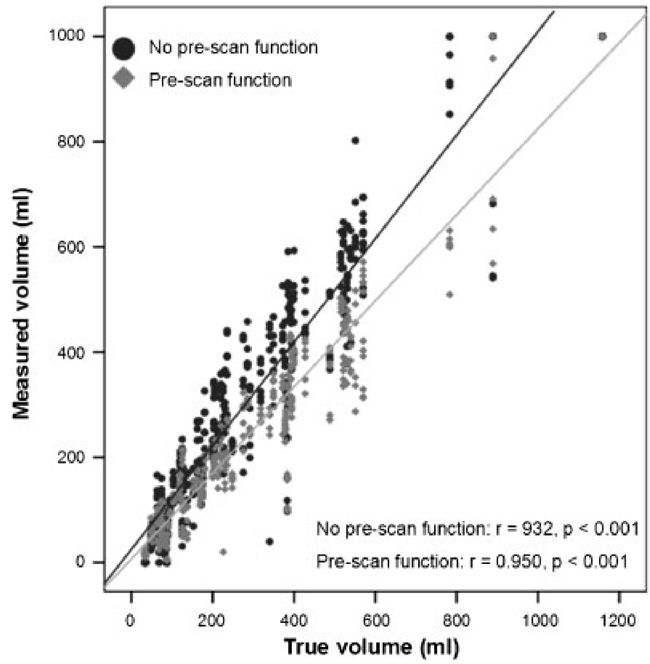

Fig. 2. Correlation of the measured volumes by the two portable bladder ultrasound bladder scanners.

RESULTS

The mean age was 57.9 years old (range 19–81) and the mean body mass index was 23.8 kg/m^2 (range 17.8–31.9). The mean PVR volume was 265.1 ml (range 33–1,158) from the catheterization, 290.9 ml (range 0–1,000) from the bladder scanner without RPI ($P = 0.089$), and 239.2 ml (range 4–1,000) from the bladder scanner with RPI ($P = 0.102$). It took an average of 22.3 sec (range 15–42) and 42.2 sec (range 13–100) to complete three measurements using both devices ($P < 0.001$), respectively. Two patients experienced mild gross hematuria related to urethral catheterization which was managed conservatively.

PVR measurements using both devices correlated very highly with the true volume in the overall volume range (Fig. 2). The Pearson correlation coefficients for the correlation between the PVR volume measured by each device and the true volume were 0.932 for the bladder scanner without RPI and 0.950 for the bladder scanner with RPI. Pearson correlation coefficients were not different according to the types of devices ($P = 0.115$).

A statistically significant difference in PDV according to the bladder volume status (>200 ml) was noted between the two devices (Fig. 3). The bladder scanner without RPI tended to overestimate the true volume in moderate volume ranges (>100 ml) by a mean PDV of 16.3%, while the bladder scanner with RPI underestimated the true volume in the whole volume range by a mean PDV of −14.1% ($P < 0.001$).

Repeated measures ANOVA showed no significant interobserver variability ($P = 0.977$ for the bladder scanner without RPI and $P = 0.853$ for the bladder scanner with RPI) or intraobserver variability ($P = 0.660$ for the bladder scanner without RPI and $P = 0.271$ for the bladder scanner with RPI). However, although different for each examiner, the gap between the highest and lowest measured values was significantly wider in the bladder scanner without RPI than in the bladder scanner with RPI, especially in lower bladder volumes (<300 ml) (Table I).

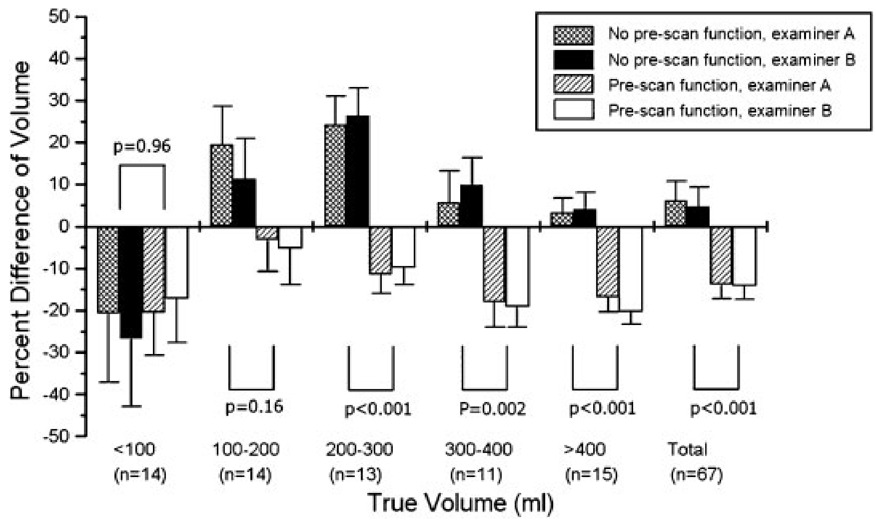

Fig. 3. Percentage of differences of volume according to the bladder volume status (>200 ml).

DISCUSSION

Accurate PVR measurements are important for diagnosing voiding dysfunction and making a decision regarding treatment. Although urethral catheterization has been accepted as the gold standard for PVR measurements, this may cause discomfort for patients and carry a risk of urinary tract infection and trauma.[2] To overcome these limitations, noninvasive ultrasound bladder volume measurement has been used as an alternative to urethral catheterization.[1,3–5]

Traditionally, ultrasound bladder volume estimation can be performed in two ways; either by using real-time ultrasound to directly visualize the bladder[4,6–8] or by using a portable bladder scanner to calculate the volume automatically without directly visualizing the bladder. The portable bladder scanner has many advantages over real-time ultrasound. It is easy to use, requires only basic training, and can be carried out on the ward, freeing up precious radiology department resources. Since it was initially reported to correlate with catheterized volumes with an r^2 of 0.80,[9] subsequent studies found that the bladder scanner without RPI had a good correlation and agreement with the true bladder volume.[6,10] However, the disadvantage of the bladder scanner without RPI is that it does not allow the operator to visualize the bladder directly. Thus, we could speculate that the pre-scan function increases measurement accuracy and decreases the variability between measurements with respect to devices that do not have such a function.

To our knowledge, there are few studies to compare the accuracy of both the conventional blind portable ultrasound bladder scanner and the bladder scanner equipped with RPI for the assessment of bladder volume. Ghani et al.[11] compared Bardscan (Bard, Crawley, UK), which combines real-time ultrasonography with bladder volume calculation, with the BVI-3000 and 3-D US system (HDI-4000, Phillips Medical Systems, Best, the Netherlands) in 50 healthy volunteers. In the Bardscan there are two planes, vertical and horizontal, by which the bladder volume can be measured. Because the bladder volume measured by Bardscan was significantly different from the voided volume, they concluded that Bardscan is not as accurate as BVI-3000 or 3-D US system. However, they used the voided volume, which do not represent all the volume in the bladder, as a point of reference. In our study, we used the urethral catheterized volume as the true bladder volume. It is generally believed that urine volumes obtained by urethral catheterization are the most accurate for PVR measurement. However, some authors reported that urethral catheterization is not as accurate in determining PVR volume as is generally perceived.[12–14] This can be explained by the surplus length of the catheter during use and the position of the eyelets far from the bladder neck, which may result in incomplete emptying. To make up for the weakness, we pulled the catheter out slowly, stopping anytime the urine flows to be sure all the urine had drained.

TABLE I. Intraobserver Variability Measured by the Maximal Range of Gap Using Each Bladder Scanner According to the True Volume Range

		Variability by examiner A			Variability by examiner B		
True volume (ml)	No. of patients	No pre-scan function	Pre-scan function	*P*-value	No. pre-scan function	Pre-scan function	*P*-value
<100	14	28.3 ± 20.3	14.9 ± 10.8	0.018	28.2 ± 23.7	13.4 ± 9.2	0.025
100–200	14	37.9 ± 19.4	15.4 ± 9.7	0.001	60.0 ± 27.0	22.2 ± 10.5	<0.001
200–300	13	83.2 ± 72.3	29.5 ± 48.2	0.059	56.0 ± 38.8	21.0 ± 22.0	0.008
300–400	11	50.1 ± 42.8	18.9 ± 6.9	0.029	89.2 ± 108.5	38.9 ± 29.4	0.159
>400	15	81.2 ± 66.0	44.3 ± 40.2	0.045	74.8 ± 57.8	58.3 ± 60.8	0.381
Total	67	56.4 ± 53.2	25.0 ± 30.8	<0.001	60.7 ± 58.5	30.9 ± 36.4	<0.001

Maximal range of gap using each bladder scanner for three times of measurements.

A good correlation does not necessarily indicate a good clinical agreement.[15] Thus, we evaluated the interobserver and intraobserver variation, PDV and the gap between the highest and lowest measured values as well as correlation coefficients for evaluating the accuracy and agreement of the measurements. We performed PDV analysis for evaluating the accuracy of the measurement because the relative value of error, rather than the absolute value of error, may be important for a given actual bladder volume.[1] Also, many researchers have used Bland-Altman analysis in that situation.[11] Bland-Altman analysis is a useful method to analyze the agreement between two different systems. However, Bland-Altman approach also has some limitations when differences are not constant over the measuring interval.[16] In these cases the mean and 95% confidence intervals of the differences do not appropriately describe the agreement or deviation between two systems. In our study, although the bladder volume measured by portable ultrasound bladder scanners with either blind mode or pre-scan mode correlated very well with the true volume, the gap between the highest and lowest measured values was significantly wider in the bladder scanner without RPI than in the bladder scanner with RPI, especially in lower bladder volumes. This means that the bladder scanner with RPI might have an advantage over the bladder scanner without RPI regarding the agreement by pointing to the bladder exactly prior to the actual measurement of bladder volume. The bladder scanner without RPI (BVI-3000 BladderScan) used in this study was already on the market for a decade. The more recently developed bladder scanners commercially available already might represent significant improvements over their predecessors.

The accuracy of the measured volume might be affected by the bladder volume status, which leads to different bladder configuration. Although the more recently developed devices represent significant improvements, there have been changes in accuracy according to the bladder volume status. Ghani et al.[11] reported that the bladder scanner without RPI may overestimate the measured volume when faced with large bladder volumes; however, other investigators have produced different results.[17–20] According to other investigators, the reasons for underestimation or overestimation include irregular shape of the bladder, continued bladder filling during the delay before catheterization, and failure of the scan to include all parts of the bladder because of large bladder volume.[21–23] We speculated that the bladder scanner with RPI could make real progress in improving the accuracy of the PVR measurement by using the pre-scan function. However, contrary to our expectation, there was no difference in the accuracy between the two devices. This was probably due to the large scan plane of the bladder scanner without RPI; it was likely already large enough to have a good correlation with the true volume.[1,24–26]

CONCLUSIONS

Our results showed that bladder volume measured by portable ultrasound devices with or without RPI correlates very well with the actual volume. Exact pointing to the bladder prior to actual measurement of bladder volume using a pre-scan function seems to reduce the variability of measured values in the bladder scanner with RPI.

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REFERENCES

1. Byun SS, Kim HH, Lee E, et al. Accuracy of bladder volume determinations by ultrasonography: Are they accurate over entire bladder volume range? Urology 2003;62:656–60.
2. Schaeffer AJ, Chmiel J. Urethral meatal colonization in the pathogenesis of catheter-associated bacteriuria. J Urol 1983;130:1096–9.
3. Griffiths CJ, Murray A, Ramsden PD. Accuracy and repeatability of bladder volume measurement using ultrasonic imaging. J Urol 1986;136:808–12.
4. Simforoosh N, Dadkhah F, Hosseini SY, et al. Accuracy of residual urine measurement in men: Comparison between real-time ultrasonography and catheterization. J Urol 1997;158:59–61.
5. Filgueiras MF, Lima EM, Sanchez TM, et al. Bladder dysfunction: Diagnosis with dynamic US. Radiology 2003;227:340–4.
6. Bano F, Arunkalaivanan AS, Barrington JW. Comparison between bladderscan, real-time ultrasound and suprapubic catheterisation in the measurement of female residual bladder volume. J Obstet Gynaecol 2004;24:694–5.
7. Hartnell GG, Kiely EA, Williams G, et al. Real-time ultrasound measurement of bladder volume: A comparative study of three methods. Br J Radiol 1987;60:1063–5.
8. Kiely EA, Hartnell GG, Gibson RN, et al. Measurement of bladder volume by real-time ultrasound. Br J Urol 1987;60:33–5.
9. Cardenas DD, Kelly E, Krieger JN, et al. Residual urine volumes in patients with spinal cord injury: Measurement with a portable ultrasound instrument. Arch Phys Med Rehabil 1988;69:514–6.
10. Dudley NJ, Kirkland M, Lovett J, et al. Clinical agreement between automated and calculated ultrasound measurements of bladder volume. Br J Radiol 2003;76:832–4.
11. Ghani KR, Pilcher J, Rowland D, et al. Portable ultrasonography and bladder volume accuracy—a comparative study using three-dimensional ultrasonography. Urology 2008;72:24–8.
12. Biering-Sorensen F, Hansen HV, Nielsen PN, et al. Residual urine after intermittent catheterization in females using two different catheters. Scand J Urol Nephrol 2007;41:341–5.
13. Jensen AE, Hjeltnes N, Berstad J, et al. Residual urine following intermittent catheterisation in patients with spinal cord injuries. Paraplegia 1995;33:693–6.
14. Stoller ML, Millard RJ. The accuracy of a catheterized residual urine. J Urol 1989;141:15–6.
15. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1986;1:307–10.
16. Geistanger A, Berding C, Vorberg E, et al. Local regression: A new approach for measurement system comparison analysis. Clin Chem Lab Med 2008;46:1211–9.
17. Schnider P, Birner P, Gendo A, et al. Bladder volume determination: Portable 3-D versus stationary 2-D ultrasound device. Arch Phys Med Rehabil 2000;81:18–21.
18. Goode PS, Locher JL, Bryant RL, et al. Measurement of postvoid residual urine with portable transabdominal bladder ultrasound scanner and urethral catheterization. Int Urogynecol J Pelvic Floor Dysfunct 2000;11:296–300.
19. Alnaif B, Drutz HP. The accuracy of portable abdominal ultrasound equipment in measuring postvoid residual volume. Int Urogynecol J Pelvic Floor Dysfunct 1999;10:215–8.
20. Borrie MJ, Campbell K, Arcese ZA, et al. Urinary retention in patients in a geriatric rehabilitation unit: Prevalence, risk factors, and validity of bladder scan evaluation. Rehabil Nurs 2001;26:187–91.
21. Ireton RC, Krieger JN, Cardenas DD, et al. Bladder volume determination using a dedicated, portable ultrasound scanner. J Urol 1990;143:909–11.
22. Coombes GM, Millard RJ. The accuracy of portable ultrasound scanning in the measurement of residual urine volume. J Urol 1994;152:2083–5.
23. Riccabona M, Nelson TR, Pretorius DH, et al. Distance and volume measurement using three-dimensional ultrasonography. J Ultrasound Med 1995;14:881–6.
24. Demaria F, Amar N, Biau D, et al. Prospective 3D ultrasonographic evaluation of immediate postpartum urine retention volume in 100 women who delivered vaginally. Int Urogynecol J Pelvic Floor Dysfunct 2004;15:281–5.
25. Barrington JW, Edwards G, Ashcroft M, et al. Measurement of bladder volume following cesarean section using bladderscan. Int Urogynecol J Pelvic Floor Dysfunct 2001;12:373–4.
26. Araki Y, Ishibashi N, Sasatomi T, et al. Effectiveness of the portable ultrasound bladder scanner in the measurement of residual urine volume after total mesorectal extirpation. Minim Invasive Ther Allied Technol 2003;12:245–8.