Bladder Volume Determination: Two-dimensional Versus Three-dimensional Transvaginal Ultrasound

Ching-Chung Liang, Tien-Yung Wei[1], Shuenn-Dhy Chang, Ching-Chang Hsieh*

Department of Obstetrics and Gynecology, Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Taoyuan, and [1]Department of Obstetrics and Gynecology, Tungs' Taichung MetroHarbor Hospital, Taichung, Taiwan.

SUMMARY

Objective: To compare the results of *in vivo* measurement of bladder volume using three-dimensional (3D) ultrasound with that obtained from 2D ultrasound

Materials and Methods: Forty female inpatients with benign gynecologic diseases had urinary bladder volume determined by ultrasound before surgery. Each patient was initially scanned using the conventional transvaginal 2D ultrasound method, followed by transvaginal 3D ultrasound, and finally underwent sterilized catheterization to obtain the actual bladder volume. The relationships between actual bladder volume and each of the 2D and 3D scan volumes were determined.

Results: The patients' bladder volumes varied from 30 mL to 590 mL. The mean value of the error measurement using transvaginal 2D ultrasound estimation was 15.7%, and the correlation coefficient was 0.90. The mean value of the error measurement using transvaginal 3D ultrasound estimation was –8.48%, with a correlation coefficient of 0.97.

Conclusion: Our data showed that the 3D scan tended to underestimate the actual bladder volume, while the 2D scan tended to overestimate it. Nevertheless, each method would suffice as a reliable noninvasive means of predicting actual bladder volume. [*Taiwan J Obstet Gynecol* 2009;48(3):258–261]

Key Words: bladder volume, three-dimensional ultrasound, transvaginal ultrasound, two-dimensional ultrasound

Introduction

Measurement of post-void residual bladder volume is important in the assessment of bladder function in women who have received anti-incontinence surgery, urogenital prolapse repair or radical hysterectomy, and in women with urinary retention after surgery or vaginal delivery. Traditionally, measurement of post-void bladder volume has involved the passage of a urethral catheter to empty the bladder, but this may cause discomfort for the patient and carry a risk of urinary infection or urethral trauma [1]. Ultrasonic imaging provides a possible alternative method for estimating bladder volume noninvasively. In previous reports, bladder volume could be accurately estimated with two-dimensional (2D) ultrasound by a transabdominal or transvaginal approach [2–4]. 2D scan volume estimates were based using ellipsoid or spherical equations to calculate the volume of a regular geometric organ shape [2,3]. However, volume estimates in irregularly shaped objects are often inaccurate, and thus various techniques have been devised to improve the accuracy of ultrasound volume measurement [5]. Most recently, 3D ultrasound has been introduced into clinical use and has demonstrated a high degree of reproducibility and accuracy of volume estimation both *in vitro* and *in vivo* [6]. This study was undertaken to assess the accuracy of *in vivo*

**Correspondence to:* Dr Ching-Chang Hsieh, Department of Obstetrics and Gynecology, Chang Gung Memorial Hospital, 199, Duenhua North Road, Taipei 105, Taiwan.
E-mail: doctor717@gmail.com
Accepted: July 24, 2008

measurement of bladder volume using transvaginal 3D ultrasound and to compare the results with those of 2D ultrasound measurement.

Materials and Methods

During the period from November 2002 to March 2003, a total of 40 female patients undergoing benign gynecologic surgery were invited to participate in this study with obtained consent. Indications for surgery included uterine myoma, adenomyosis, ovarian mass, urodynamic stress incontinence, and urogenital prolapse. All bladder volume measurements were performed by a single investigator (C.C.L.) before the patients were sent to the operating theater. At the beginning of the examination, the patients were placed in the supine position for transvaginal ultrasound examination of the bladder and urethral tissues. Both 2D and 3D scan bladder volumes were estimated by a 7.5-MHz transvaginal transducer with a Voluson 730 ultrasound machine (GE Medical Systems, Zipf, Austria).

Each bladder was first scanned using the conventional 2D ultrasound method. The 2D ultrasound bladder volume was estimated by measuring the height and depth of the bladder. The data was stored in the computer and calculated later by the formula introduced by Haylen et al [2]: estimated bladder volume (mL) = $(5.9 \times H \times D) - 14.6$, where H represents the maximum bladder diameter in the horizontal axis (cm) and D represents the maximum bladder diameter in the vertical axis (cm).

After measuring the height and depth as described above, the 3D ultrasound bladder volume was measured immediately with the same vaginal probe. The patient was asked to remain as still as possible, and every effort was made by the investigator to limit inappropriate movements of the transducer. The truncated sector defining the region of interest was adjusted, and the sweep angle was set to 85° to ensure that a complete bladder scan was obtained. The volumes were captured through automatic sweep of the transducer over the region of interest when the "scan" button was depressed. The images were digitally stored in the computer and analyzed using the GE Kretz 4D view, version 5.0, software package (GE Kretztechnik GmBH, Zipf, Austria) for 3D scanning later. It took around 5 minutes to complete an entire scanning procedure. On activation of the 3D image data stored in the computer, three orthogonal planes were simultaneously displayed on the screen. The orientation of these planes was maintained throughout any translation and rotation. The 3D bladder volume was measured by outlining the bladder border of each plane manually using a mouse ball. A total of 12 ultrasonic images, spatially interlocked, were generated at 15° angles to one another. From these individual images, a volumetric model of the whole bladder was constructed and the 3D volume was calculated by the built-in computer program.

Indwelling catheterization was performed by the investigator with a 14F catheter, a routine procedure for every patient before undergoing a major gynecologic operation in our institute. The catheterized volume of the urine specimen was measured in a cylinder with milliliter graduation, and then compared with the measured bladder volume by 2D and 3D ultrasound. Results were presented as mean ± standard deviation and Pearson's correlation coefficient (r), with a p value < 0.05 considered statistically significant for all tests. Normality was estimated using the Kolmogorov-Smirnov test. Statistical analyses were performed using SPSS version 11.0 (SPSS Inc., Chicago, IL, USA) for Windows.

Results

The patients' demographic data and bladder volume measured by 2D and 3D ultrasound and transurethral catheter are shown in the Table. Scan volume was correlated with catheter volume using both 2D and 3D ultrasound methods (Figures 1 and 2). The correlation coefficients of the 2D and 3D methods were 0.90 and 0.97, respectively. Comparing the scan volumes of the 2D and 3D measurements with the catheter volume, we found the mean values of the error measurements were 15.7% ± 27.7% (range, –62.1% to 69.4%) for the 2D ultrasound method and –8.4% ± 16.3% (range, –31.7% to 43.1%) for the 3D ultrasound group.

For intraobserver variability evaluation, reliability assessment of measurement of bladder volume was performed by calculating another 12 patients' bladder volumes with transvaginal 2D and 3D ultrasound without catheterization. The results showed not only that there was a good correlation in the consecutively repeated measurements, but also that the difference between the two repeated measurements was also not significant ($p > 0.05$). In addition, since all the measurements were performed by the same investigator in this study, there were no concerns regarding interobserver variability.

Discussion

The use of transurethral catheterization to measure bladder volume is not without risks, including pain,

Table. Characteristics of patients ($n=40$)

	Mean ± SD	Range	*n* (%)
Age (yr)	51.3 ± 10.3	30–82	
BMI (kg/m^2)	25.7 ± 3.5	18.6–34.3	
Parity	3.3 ± 1.7	1–7	
Menopausal status			
Premenopausal			27 (67.5)
Postmenopausal			13 (32.5)
Diagnosis			
Uterine and ovarian mass			20 (50)
Urinary incontinence			14 (35)
Urogenital prolapse			6 (15)
Bladder volume (mL)			
2D ultrasound	254.6 ± 157.8	11–740	
3D ultrasound	198.1 ± 127.2	25–547	
Catheter	223.6 ± 148.7	30–590	

SD = standard deviation; BMI = body mass index; 2D = two-dimensional; 3D = three-dimensional.

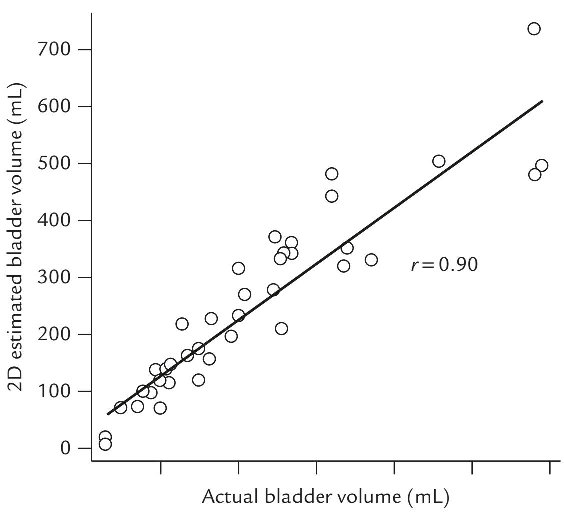

Figure 1. Scattergram of catheter volume versus transvaginal two-dimensional (2D) scan volume.

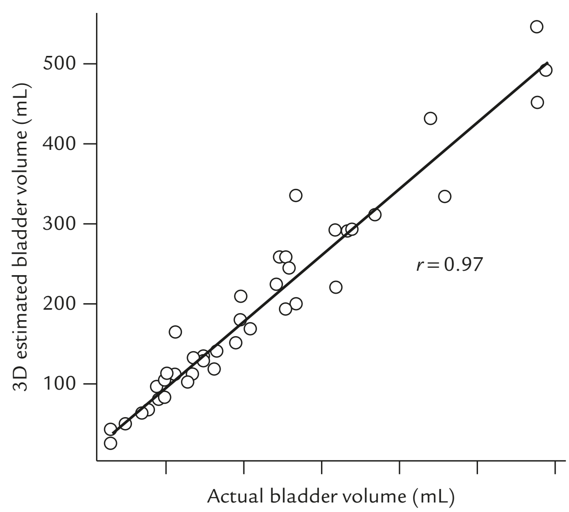

Figure 2. Scattergram of catheter volume versus transvaginal three-dimensional (3D) scan volume.

hematuria, and urinary tract infection, which occur in at least 2% of patients [7]. We believe that it is beneficial for patients to have a bladder ultrasound instead of a catheterization procedure for bladder volume assessment. Furthermore, previous results had demonstrated that 2D and 3D ultrasonic imaging are capable of closely reflecting the actual bladder volume [2–4,6,8,9], within a range of 10–23% [2,6].

In order to overcome the limitations of abdominal ultrasound at smaller bladder volumes, Haylen et al developed the formula volume, $5.9 \times (\text{height} \times \text{depth}) - 14.6$ mL, for application to measurements of bladder volume by transvaginal linear array ultrasound. They reported that the mean error in bladder volume in the range of 10–175 mL was 23%, and the correlation coefficient was 0.94. In this study, we adopted the formula of Haylen et al to measure bladder volume and achieved compatible results with a correlation coefficient of 0.90. We also found that 2D ultrasound overestimated the actual bladder volume (mean error, 15.7%). The reasons for overestimation, according to other investigators, included difficulties in measuring the height and depth of the bladder because of its irregular shape and being unable to view the entire bladder in a single scan [6].

Our results showed that 3D ultrasound estimation was better correlated with catheter volume than 2D ($r=0.97$ *vs.* $r=0.90$), indicating that 3D ultrasound was more accurate than 2D for estimating bladder volume.

Before our study, only the study by Riccabona et al [6] was available to compare measurements from 2D and 3D technologies with actual bladder volumes. They demonstrated that 3D scan volume measurements had an overall mean absolute error of 4.9%, in contrast to 27.5% for 2D ultrasound measurements. In our study, the correlation coefficient of the 3D method was 0.97, with 3D ultrasound underestimating the actual bladder volume (mean value of the error, –8.4%). The scan underestimation, also noted by others [10,11], could be partly explained by continued bladder filling during the delay before catheterization, or failure of the scan to include all parts of the bladder because of the large bladder volume. In fact, the actual bladder volumes of five patients were over 400 mL in our study. In the study of Marks et al [12], accuracy of the determination of bladder volume was tested by comparing a portable 3D scan with catheter volumes in 182 consecutive adult outpatients; the ultrasound measurements were found to be predictive of actual catheter volumes ($r = 0.90$) across the range between 0 and 1,015 mL bladder volume. Marks et al documented that the scan volumes consistently underestimated the catheter volumes, although differentiations between low and high bladder volumes were not determined. By contrast, Schnider et al found that both 2D and 3D ultrasound devices overestimated bladder volumes at lower fillings (bladder volume < 160 mL), and underestimated volumes at higher fillings (bladder volume > 160 mL). They also found that the 2D device showed better reproducibility, particularly at lower bladder volumes [13].

In conclusion, our data showed that 3D ultrasound underestimated the actual bladder volume, while 2D overestimated it. 3D ultrasound was more accurate than 2D in estimating bladder volume. Nevertheless, both measurement results correlated well with the actual bladder volume and, therefore, are suitable for serving as noninvasive alternatives to catheterization.

References

1. Schaeffner AJ, Chmiel J. Urethral meatal colonization in the pathogenesis of catheter-associated bacteria. *J Urol* 1983; 130:1096–9.
2. Haylen BT, Frazer MI, Sutherst JR, West CR. Transvaginal ultrasound in the assessment of bladder volumes in women: preliminary report. *Br J Urol* 1989;63:149–51.
3. Griffiths CJ, Murray A, Ramsden PD. Accuracy and repeatability of bladder volume measurement using ultrasonic imaging. *J Urol* 1986;136:808–12.
4. Yip SK, Fung TY, Chung TKH. Ultrasonographic estimation of postpartum postvoid residual bladder volume: a comparison between transabdominal and transvaginal ultrasonography. *Int Urogynecol J Pelvic Floor Dysfunct* 1998;9:9–12.
5. Knorr H, Strauss I, Seichert N. Ultrasound cystometry with reference to urinary bladder form and bladder filling. *Ultraschall Med* 1990;11:150–4. [In German]
6. Riccabona M, Nelson TR, Pretorius DH, Davidson TE. Distance and volume measurements using three-dimensional ultrasound. *J Ultrasound Med* 1995;14:881–6.
7. Meares EM Jr. Current patterns in nosocomial urinary tract infections. *Urology* 1991;37(3 Suppl):9–12.
8. 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;15:627–32.
9. Haylen BT. Residual urine volumes in a normal female population: application of transvaginal ultrasound. *Br J Urol* 1989;64:347–9.
10. Ireton RC, Krieger JN, Cardenas DD, Williams-Burden B, Kelly E, Souci T, Chapman WH. Bladder volume determination using a dedicated, portable ultrasound scanner. *J Urol* 1990;143:909–11.
11. Coombes GH, Millard RJ. The accuracy of portable ultrasound scanning in the measurement of residual urine volume. *J Urol* 1994;152:2083–5.
12. Marks LS, Dorey FJ, Macairan ML, Park C, deKernion JB. Three-dimensional ultrasound device for rapid determination of bladder volume. *Urology* 1997;50:341–8.
13. Schnider P, Birner P, Gendo A, Ratheiser K, Auff E. Bladder volume determination: portable 3-D versus stationary 2-D ultrasound device. *Arch Phys Med Rehabil* 2000;81:18–21.