Original Article

Is portable three-dimensional ultrasound a valid technique for measurement of postpartum urinary bladder volume?

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ABSTRACT

Objective: To determine the accuracy of bladder volume (BV) measurement and to identify factors that influenced the ultrasound bladder scanner (UBS) measurement of BV in postpartum women compared with transurethral catheterization.

Materials, methods and results: A total of 190 paired measurements were performed on 190 women aged between 16 and 47 years. Majority of the women (36.9%) were in their first parity (range: 1–9). The mean BV was 159.46 mL (standard deviation (SD) = 99.78; range: 17–593 mL) on three-dimensional (3D) UBS and 143.76 mL (SD = 104.89; range: 2–588 mL) on catheterization. The mean difference between the two values was 15.70 mL (SD = 69.31, p < 0.001). The Foley’s catheter was clamped for a minimum of 30 minutes and a maximum of 260 minutes. The UBS measurements were highly correlated with the BV obtained by catheterization (r = 0.819; p < 0.001). There was no significant difference between UBS and catheterized volume in a different volume subgroup. There were 35 cases (18.2%) with the difference in measurement of more than 25%. Twenty-five cases were associated with a catheterized volume less than 50 mL. There were a total of 33 cases with true BV of less than 50 mL, and only eight cases (24.24%) had an accurate measurement. The UBS tends to overestimate BV between 2 and 270 mL in this group. There was a significant linear relationship between the difference in measurement and body weight and duration of clamping.

Conclusion: Measurement of BV in immediate postpartum period using UBS is comparable with urethral catheterization. The accuracy of measurement is affected by body weight and increasing amount of BV.

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Introduction

Portable ultrasound scanning has been developed as a convenient noninvasive method for measuring bladder volume (BV), especially postvoid residual (PVR) urine, and as an alternative to in-and-out catheterization. This method is relatively quick, safe, painless, and demands little cooperation from the patient in an office setting without the need for specially trained technicians [1]. It also reduces psychological stress and possible physical problems to patients, especially during the postpartum period. It has the ability to eliminate the sources of error from urethral catheterization, particularly the diuresis effect, adequacy of bladder drainage, and accuracy of measuring apparatus. A 14FG Foley’s catheter will leave an average of 1 mL postcatheterization BV, whereas a short plastic catheter will leave an average of 77 mL [2]. Accurate measurement of PVR can be affected by diuresis factor if there is a delay between voiding and PVR measurement. Ultrasonic techniques can measure PVR within 60 seconds of voiding compared with PVR measurement by urethral catheterization, which can be achieved efficiently within 5 minutes of voiding or inefficiently up to 10–16 minutes [3]. Although urethral catheterization is the most accurate method for PVR measurement, it is known to cause urethral trauma and urinary tract infection [2].

The accuracy and reproducibility of these portable ultrasound bladder scanners (UBSs) have been evaluated previously [1,3–5], especially for patients with normal sized uterus or without uterus. However, data regarding the application of UBS on
postpartum women are limited and conflicting. Although standard ultrasonography used either transabdominally or transvaginally immediately after childbirth gives accurate results [6], it is not clear whether the enlarged postpartum uterus has any adverse effects on the accuracy of the bladder scan. Measurements could be inaccurate due to the specific shape and size of the uterus in this particular period. It is also possible that the scan would measure the blood within the uterus instead of volume of the bladder [7]. We conducted this study to determine the accuracy of BV measurement and to identify factors that influenced the UBS measurement of BV in postpartum women compared with transurethral catheterization.

**Materials and methods**

A cross-sectional study was conducted in a tertiary referral hospital, between September 1 and November 30, 2010. The patients were women who had undergone cesarean section and on Foley’s catheter postoperatively. Approval from the hospital ethics committee and Malaysian Clinical Research Committee (NMRR-10-842-6453) was obtained before recruiting the patients. The UBS device used was BVI 3000. It is a compact (<3 kg) battery-powered ultrasound unit that consists of a hand-activated, sector array B mode, 2-MHz scan heads with a 120° scan angle, portable liquid crystal displays that show the bladder shape, aiming icons, current scan and maximum scan volumes, and built-in printers. The measurement was performed by the third author who was trained in using ultrasound devices as well as in-and-out catheterization. It is our practice to use 16F Foley’s catheter for all patients who had undergone cesarean section.

Consent was obtained from the patients before their recruitment. The demographic data and other parameters such as age, parity, uterine size, height, and body weight were also recorded to examine for possible confounders. The measurement was performed on Day 1 after operation in conjunction with our hospital policy to keep indwelling catheter for 24 hours. First, the urine bag was removed and the catheter was clamped for a minimum of 30 minutes. Immediately after deflating the catheter balloon, the UBS head was placed suprapublically two finger breaths above the symphysis pubis with the patients in supine position. Every effort was made to capture the bladder image in the crosshair target on the digital screen of the UBS; this entailed angulating the scan head in various angles and directions. This is in accordance with the manufacturer’s medical physics guidelines for achieving optimal accuracy. Three readings using UBS were acquired from each woman consecutively. The clamp was removed from the urethral catheter and the bladder was emptied by aspiration using a 50-mL syringe immediately or within 5 minutes following bladder scan measurement. The Foley’s catheter was then slowly withdrawn with continuous gentle aspiration to collect any remaining urine. Complete evacuation of the bladder was further confirmed by performing two-dimensional (2D) scan. The total aspirated volume was then determined. The time interval between BV measurement and the final catheter aspiration was recorded.

Women who required long-term indwelling catheter or those with serious obstetrics or medical problems, pelvic mass (i.e., uterine myoma, ovarian cyst, and uterine abnormality), and intraoperative bladder injury (past or present) were also excluded.

Data were analyzed using SPSS software version 16 (SPSS Inc., Chicago, IL, USA). Correlations between BV and associated factors were evaluated by Pearson correlation analysis. The relationship between BV and the associated factors was then tested using regression analyses. A p value < 0.05 was taken to be significant.

**Results**

A total of 190 paired measurements were performed on 190 women aged between 16 and 47 years. Majority of the women (36.9%) were in their first parity (range: 1–9). The mean BV was 159.46 mL [standard deviation (SD) = 99.78; range: 17–593 mL] on three-dimensional (3D) UBS and 143.76 mL (SD = 104.89; range: 2–588 mL) on catheterization. The mean difference between the two values was 15.70 mL (SD = 69.31, p < 0.001). The Foley’s catheter was clamped for a minimum of 30 minutes and a maximum of 260 minutes. The sample demographic features are further described in Table 1. The catheterization BV versus volumes obtained by UBS was plotted on a scatter plot and compared (Fig. 1). The UBS measurements were highly correlated with the BV obtained by catheterization (r = 0.819; p < 0.001).

For a more precise measurement, the volume was further subdivided into a smaller subgroup (Fig. 2). There was no significant difference between UBS and catheterized volume in a different volume subgroup. There were 35 cases (18.2%) with the difference in measurement of more than 25%. Twenty-five cases were associated with a catheterized volume less than 50 mL. There was a total of 33 cases with true BV of less than 50 mL, and only eight cases (24.24%) had an accurate measurement. The UBS tends to overestimate BV between 2 and 270 mL in this group.

There was a significant linear relationship between the difference in measurement and body weight and duration of clamping. Those with 1 U increase in body weight and 1 minute more clamping duration had a higher difference of 0.30 [95% confidence interval (CI): 0.012, 0.58] and 0.80 (95% CI: 0.13, 1.48), respectively. However, the difference between the two methods of BV measurement was not affected by parity, age, body mass index (BMI), and uterine size as shown in Table 2.

**Discussion**

The risk of postpartum urinary retention (PUR) varies between 0.05% and 14.1% in deliveries. It is higher among Asian women and those with prolonged first and second stage of labor, previous history of PUR, and epidural analgesia [8,9]. Use of clinical signs and symptoms alone to detect PUR may however be misleading. The

**Table 1**

Clinical characteristics of patients (N = 190).

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Mean (SD)</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>29.86 (5.54)</td>
<td></td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.54 (0.06)</td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>67.01 (14.46)</td>
<td></td>
</tr>
<tr>
<td>BMI</td>
<td>28.15 (5.49)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Underweight</td>
<td>3 (01.6)</td>
</tr>
<tr>
<td></td>
<td>Normal</td>
<td>51 (26.7)</td>
</tr>
<tr>
<td></td>
<td>Overweight</td>
<td>79 (41.4)</td>
</tr>
<tr>
<td></td>
<td>Obese</td>
<td>57 (30.4)</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-Malay</td>
<td>23 (12.10)</td>
</tr>
<tr>
<td></td>
<td>Malay</td>
<td>167 (87.90)</td>
</tr>
<tr>
<td>Parity</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Para 1</td>
<td>70 (36.8)</td>
</tr>
<tr>
<td></td>
<td>Para 2–5</td>
<td>110 (58.0)</td>
</tr>
<tr>
<td></td>
<td>Para 6 &amp; above</td>
<td>10 (5.2)</td>
</tr>
<tr>
<td>Fundal height (cm)</td>
<td>16.11 (2.38)</td>
<td></td>
</tr>
<tr>
<td>Type of analgesia</td>
<td>General</td>
<td>2 (1.10)</td>
</tr>
<tr>
<td></td>
<td>Spinal</td>
<td>188 (98.9)</td>
</tr>
<tr>
<td>Interval between catheterization and scan (min)</td>
<td>3.03 (1.21)</td>
<td></td>
</tr>
<tr>
<td>Duration of clamping (min)</td>
<td>153.72 (34.20)</td>
<td></td>
</tr>
<tr>
<td>Catheterization volume (ml)</td>
<td>143.76 (104.89)</td>
<td></td>
</tr>
<tr>
<td>Mean scan volume (ml)</td>
<td>159.46 (99.78)</td>
<td></td>
</tr>
</tbody>
</table>
Retention may be missed or it may lead to unnecessary catheterization. Al-Shahrani and Lovatsis [10] found that symptoms of obstructive voiding did not correlate with measured PVR in their cross-sectional study on 134 women with symptomatic voiding difficulties who were referred to a tertiary urology clinic.

Urethral catheterization is a gold standard in the measurement of BV and mandatory in certain circumstances. For the past four decades the use of a portable ultrasound device has grown in popularity because it is noninvasive, easy to use, faster, comfortable, and readily accepted by both patient and staff. There is no risk of infection, trauma, radiation, and the procedure does not require mathematical calculation [1,3].

UBS is now widely used in obstetrics units, especially in evaluating postpartum urinary retention. BV 12000 was the first UBS introduced in 1986 followed by BVI 2000, BVI 2500, BVI 2500+, and BVI 3000. Studies on women with normal uterus using the earlier models were comparable ($r = 0.79–0.98$) with catheterization [11–16]. Because of improvements in technology, the BVI 3000 machine is now lighter, has a larger scan plane area, and faster scan time (7 seconds).

Our study reported a high correlation ($r = 0.819, p < 0.001$) between UBS and urethral catheterization, which is consistent with previous studies [17,18]. Using the same UBS machine, similar findings were documented by Barrington et al ($r = 0.807$) and Demaria et al ($r = 0.94$) who suggested its use in the peripartum period as

![Fig. 1. Correlation between catheterization and scan volume ($r = 0.82, p < 0.001$).](image1)

![Fig. 2. Differential comparison between urethral catheterization and portable ultrasound measured urine volumes according to the range of the catheterized urine volume.](image2)
initial assessment for urinary dysfunction [17,18]. Demaria et al had only assessed the accuracy of 3D UBS in the evaluation of PVR in postpartum women who delivered vaginally. By contrast, we recruited only postcesarean section women in this study because they were already on continuous bladder drainage as part of their peri-partum care. This was to avoid unnecessary urethral catheterization in women with vaginal delivery. Lee et al [19] in their prospective study on 52 women, in which 30 of them had undergone emergency cesarean section, failed to validate the use of 3D UBS compared with 2D scan except for highly reproducible readings (intermittent clean catheterization, ICC = 0.81). This result is further supported by Pallis and Wilson [20] who reported the inaccuracy of the bladder scan in estimating postpartum BV the day following vaginal delivery compared with 2D scan (r = 0.477 vs. r = 0.796).

We also assessed the accuracy of the two methods across different volume subgroups and found that UBS measurement has no significant difference compared with urethral catheterization. This contradicts the report by Lee et al [19] who suggested that UBS measurements were overestimated when the BVs were small and underestimated when the BVs were large. By contrast, Alnaiif and Drutz [4] found that bladder scan estimates were most accurate when the readings were below 50 mL and least accurate when the readings were higher than 150 mL. However, this prospective study was performed on nonpregnant women undergoing urodynamic testing using portable scan BVI 2500. This conclusion was also derived on the basis that UBS measurement was considered accurate when it was within 25% of the true BV. Using the same cutoff value, in this study we found that 35 cases (18.42%) had UBS measurements above 25% of the catheterized BV. Majority of them revealed BV < 50 mL, which accounted for 24.24% accuracy. However, problems in detecting this small BV have no significant clinical implication in diagnosing PUR.

Although portable ultrasound scanners have been widely used because of their relative automation and ease of operation, unfortunately the device is unable to distinguish between urine volume and any other fluid collections in the lower abdomen. The accuracy of BV measurement is also affected by serious abdominal scar, abnormal bladder shape, uterine prolapse, pregnancy, presence of pelvic mass, and thick abdominal wall [3]. Our regression analysis revealed that age, parity, fundal height, interval between two procedures and BMI did not influence the accuracy of the UBS measurement. These findings were consistent with Lee et al [19] except for increase in urethral volume. We found that the uterine size did not influence the 3D scan measurement except in cases with true BV of less than 50 mL. In cases with large BV, the postpartum uterus, which anatomically lies posterior to the bladder, would not influence the UBS reading. For those with small BV, the uterine size and lochia would give a false measurement, resulting in an overestimation of the true BV.

The bladder following a delivery is elongated superiorly and compressed from the anterior to posterior side, and is often levorotated. In women who had undergone cesarean section, the uterus is more suspended to the anterior abdominal wall compared with those who had vaginal delivery. Theoretically, scared uterus or pelvic adhesions might have altered the shape of the bladder. Bulging and shifting of organs can affect the contour and position of the bladder and make ultrasound results more difficult to interpret because the bladder scans calculate the BV based on a presumed ellipsoid shape. However, we did not encounter any difficulty despite having a study population with abdominal scar, which is further supported by others [17,19].

We found a significant linear relationship between difference of BV measurement and body weight and duration of clamping. Increase in body weight and BV will further increase the discrepancy between the two measurements. Although BMI did not influence the UBS measurement, high body weight might cause increases in the abdominal wall thickness. Unfortunately, the abdominal wall thickness was not measured in this study. There is a difficulty in finding the bladder in obese women because of the thick abdominal wall. However, with 3D scanner, the scan head can be angled in various directions to capture the bladder image in the crosshair target on the digital screen for optimal results [19].

The investigator who performed the bladder scan, catheterization, and 2D scan was the same person and was not blinded. However, this was minimized by a strict compliance to our protocol and the result was calculated upon completing data collection. This study only involves postcesarean section women, and therefore, the results of this study could only be generalized to this group of patients.

**Conclusion**

Measurement of BV in immediate postpartum period using UBS is comparable with urethral catheterization. The accuracy of measurement is affected by body weight and increasing amount of BV.

**References**


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