Accuracy of Post-Void Residual Urine Volume Measurement Using an Ultrasound Bladder Scanner among Postoperative Radical Hysterectomy Patients

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Background: *Postoperative urinary retention occurs in 17 to 42% of Radical hysterectomy (RH) cases. The gold standard assessment of post-void residual urine volume (PVR) is bladder catheterization. The use of the 3D portable ultrasound device (VerathonBladderScan BVI 9400) to evaluate PVR is quick, safe, non-invasive, painless, and comfortable for patients as well as being easy to use.*

Objective: *To compare the accuracy of ultrasound bladder scanner with that of urethral catheterization in the assessment of post-void residual urine volume (PVR).*

Material and Method: *This was a prospective study. After removal of Foley's catheter in postoperative radical hysterectomy(RH) patients, the voiding care schedule consisted of voids after six hours or earlier if the patient had the urge. Promptly after voiding, PVR was measured using the BladderScan (Scan volume). Immediately after the procedure, urethral catheterization was performed to obtain the actual PVR (Catheter volume). The process was repeated in subsequent voids, and correlations between scan volume and catheter volume were analyzed.*

Results: *Seventy patients (140 measurements) were included. A high correlation was found between the scan volume and the catheter volume ($r = 0.89$, $p<0.001$). A 91.0% specificity and 93.1% negative predictive value(NPV) were obtained using the scan volume in predicting a catheter volume of $\leq$100 ml. The difference in measurements between the two methods was not related to age, body mass index, parity, co-existing illness, type of surgical incision or duration of indwelling catheter. When catheter volume >100 ml was the cutoff for determining the need for re-catheterization, the scan volume returned 90.0% accuracy. Repetition of ultrasound scan in patients who had a first scan volume of $\leq$100 ml yielded a 97.2% specificity and 100% NPV in predicting catheter volume of $\leq$100 ml.*

Conclusion: *The Bladder Scan provides good correlation together with high rates of specificity and NPV, and it could be an alternative modality to catheterization for the measurement of PVR in postoperative RH patients.*

Keywords: *Bladder scanner, BVI 9400, Retention of urine, Residual urine, Radical hysterectomy*

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Radical hysterectomy (RH) with pelvic lymphadenectomy is a standard and effective surgical treatment for early-stage cervical cancer and some endometrial cancers with cervical extension. The terminal branches of the pelvic plexus which innervate the urinary bladder and urethra are unavoidably damaged during the operation, resulting in impaired bladder sensation, detrusor under-activity, and non-relaxing urethral sphincter. Postoperative urinary retention occurs in 17 to 42% of cases[1-3]. Over-distended bladder can cause frequent urinary tract infections (UTI), overflow incontinence, permanent detrusor damage, vesico-urethral reflux, pyelonephritis, and renal damage. Assessment of post-void residual urine volume (PVR) is an important part of postoperative care after removal of the indwelling Foley's catheter, which is usually retained for about seven days, to avoid extreme bladder over-distention. The gold standard assessment of PVR is bladder catheterization; however, this procedure is invasive, carries an increased risk of UTI, and can cause urethral trauma and is unpleasant for patients. The use of the 3D portable ultrasound device to evaluate PVR is quick, safe, non-invasive, painless, and comfortable for patients as well as being easy to use. Several studies have assessed the accuracy of earlier generations of portable ultrasound devices (BVI 2000, BVI 2500, BVI 3000, and BioCon-500) in general urogynecologic patients[4-7].

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The primary purpose of the present study was to evaluate the accuracy of a newer 3D portable ultrasound device (Verathon Bladder Scan BVI 9400) in the measurement of PVR. In addition, the present study evaluated the clinical application of 3D portable ultrasound among postoperative RH patients.

Material and Method

The BladderScan BVI 9400 (Bothell, WA, USA) is a portable ultrasound instrument that provides a non-invasive measurement of bladder volume. The device consists of an ultrasound probe that scans the patient's bladder and a compact, battery-operated console that provides an array of measurement-related information. Within seconds of the user's releasing the scan button (on the hand grip of the probe), the BVI 9400 measures ultrasonic reflections on multiple planes inside the body and produces a three-dimensional image. Based on this image, the BVI 9400 calculates and displays the bladder volume. If the scan is "on target" all eight arrows will flash on the probe screen, and the bladder will be shown in the center of the crosshairs on the console screen.

This was a prospective study on in-patient basis, and it was reviewed and approved by the Ethics Committee of Rajavithi Hospital. Informed consents were obtained from patients after the details of the study had been fully explained. Inclusion criteria were all postoperative RH patients undergone the operation under either laparoscopy or laparotomy. Patients who had serious intra-operative or postoperative complications or obvious surgical wound infection were excluded. Patients' demographic data were recorded. Foley's catheter was usually removed on the seventh postoperative day or earlier for RH patients depending on the radicality of surgery and surgeon preference. The voiding care schedule consisted of voids six hours after removal of the urethral catheter or earlier if the patient had the urge. Promptly after voiding (within five minutes), the patients were asked to lie in the supine position. PVR was measured using the 3D portable ultrasound (Verathon BladderScan BVI 9400), giving the scan volume. Immediately after the procedure (within five minutes), urethral catheterization was performed to obtain the actual PVR (the catheter volume). The process was performed twice for each patient. We accepted PVR $\leq$100 ml as normal for postoperative RH patients. If the Catheter volume was greater than 100 ml on two consecutive occasions, the patient was discharged and retained the urethral catheter for an additional seven days. The voiding care schedule was repeated at the postoperative clinic.

Data were presented as mean $\pm$ standard deviation (SD) or median (range) for continuous variables and number (%) for categorical variables. Pearson's correlation was used to evaluate correlations between Scan volume and Catheter volume. Sensitivity, specificity, positive predictive values, negative predictive values, and accuracy were calculated using a 2x2 table of the collected data. A *p*-value of less than 0.05 was considered to be statistically significant.

Results

Seventy-one postoperative RH patients were included in the present study, with 140 measurements. One patient was excluded because she could not void six hours after catheter removal, and 70 patients were therefore analyzed. Table 1 showed their demographic data. The catheter volume ranged from 0 to 550 ml, and the average scan volume and catheter volume were 105 ml and 130 ml respectively. A high correlation was obtained when scan volumes were plotted against catheter volumes (number of measurements = 140, correlation coefficient = 0.89, $p<0.001$) (Fig. 1). The difference in measurements between the two methods was not related to age, body mass index, parity, co-existing illness, type of surgical incision or duration of

Table 1. Patients' demographic data

Characteristics	n = 70
Age (years)	
Mean $\pm$ SD	48.21$\pm$1.11
Range	25.0-76.0
Body mass index (kg/m^2)	
Mean $\pm$ SD	24.68$\pm$4.48
Range	16.35-36.62
Parity	
Median (min-max)	3.0 (1-4)
Co-existing illness	
Yes (DM, HT, Dyslipidemia, etc.)	25 (35.7%)
No	45 (64.3%)
Diagnosis	
Cervical cancer	66 (94.3%)
Endometrial cancer	3 (4.3%)
Other	1 (1.4%)
Type of abdominal wound incision	
Transverse	13 (18.6%)
Vertical	51 (72.9%)
Keyhole (laparoscopy)	6 (8.6%)
Duration of indwelling catheter (day)	
Median (min-max)	6.50 (3-8)

indwelling catheter (Table 2). Sensitivity, specificity, positive and negative predictive values of the scan volume compared with catheter volume were calculated. When catheter volume >100 ml was the cutoff for determining the need for re-catheterization, the scan volume returned 90.0% accuracy (Table 3). On repetition of ultrasound scan in patients who had a first scan volume ≤100 ml in the present study, the scan volume showed 97.4% accuracy in predicting Catheter volume ≤100 ml (Table 4). Twenty-eight patients (40%) had a first PVR measurement >100 ml, and all these underwent a second PVR measurement after subsequent void in accordance with the voiding care schedule, at which point 20 patients (28.6%) still had PVR measurement >100 ml.

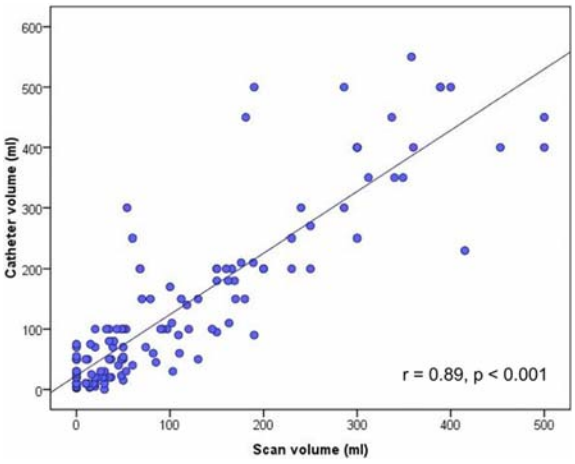

Fig. 1 Correlation of Scan volume and Catheter volume.

Discussion

Urethral catheterization is the gold standard

Table 2. Associated factors with the differences between Scan volume and Catheter volume

Factors	r	*p*-value
Age	0.061	0.476
Body mass index	0.031	0.713
Parity	0.014	0.868
Co-existing illness	0.010	0.906
Presence of abdominal wound incision	0.053	0.537
Duration of indwelling catheter	0.020	0.817

Table 3. Sensitivity and specificity of different PVR in postoperative RH patients

Scan volume (ml)	Catheter volume (ml)	Times	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
>100	>100	45	88.2	91.0	84.9	93.1	90.0
	≤100	8					
≤100	>100	6					
	≤100	81					
>150	>150	34	81.0	95.9	89.5	92.2	91.4
	≤150	4					
≤150	>150	8					
	≤150	94					

PVR = post-void residual; RH = redical hysterectomy; PPV = positive predictive value; NPV = negative predictive value

Table 4. Sensitivity and specificity in the repeated scan of patients who had the first Scan volume ≤100 ml

Scan volume (ml)	Catheter volume (ml)		Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
	>100	≤100					
>100	2	1	100.0	97.2	66.7	100.0	97.4
≤100	0	35					

PPV = positive predictive value; NPV = negative predictive value

for determining an accurate PVR; however, it is uncomfortable, invasive, and painful, and it may cause urethral trauma and UTI. Clinicians have investigated many alternative non-invasive methods, such as excretory urography, radionuclide scan, and ultrasound (both abdominal and vaginal). Each method has its drawbacks in terms of inaccuracy, high expense, or discomfort. The bladder scan device is a portable ultrasound device developed for this purpose has been in use for decades. Several studies have investigated and confirmed the accuracy of bladder scan devices developed earlier (BVI 2000, BVI 2500, BVI 3000 and BioCon-500), and the present study evaluated a newer 3D portable ultrasound device (Verathon BladderScan BVI 9400) among postoperative RH patients. A high correlation was demonstrated between the catheter volume and scan volume in the study with a correlation coefficient = 0.89, $p<0.001$, and these results are consistent with those found in previous studies of earlier models of the device (r = 0.60 to 0.98)[4-7]. The correlation coefficient found in the present study is comparable to that of using transabdominal ultrasound assessment of PVR (r = 0.93)[8]. Bozsa S demonstrated significant correlations between the PVR estimated by two different three-dimensional ultrasound volumetric methods (VOCAL and XI VOCAL) and the actual PVR (r = 0.985 and 0.990)[9]. Thickness of the abdominal wall and the presence of surgical wounds may influence the efficacy of assessment, but correlation analysis has shown that the difference is not related to abdominal wound incision or body mass index, and is in agreement with the results of the study conducted by Goode PS[4].

In patients with PVR >100 ml, re-catheterization is usually indicated[10], the 3D portable ultrasound correctly identified 91.0% (specificity), with 93.0% negative predictive value and 90.0% accuracy. According to Ghezzi et al[11] re-catheterization is indicated at PVR >150 ml, and the 3D portable ultrasound in their study had 95.9% specificity, 92.2% negative predictive value and 91.4% accuracy. Retaining amounts of PVR is not a life-threatening problem, and a short delay in initiating treatment is unlikely to harm the patients, so the criteria of PVR >150 ml may be acceptable to achieve higher specificity, resulting in fewer patients need re-catheterization. Maymon R[12] used the sonographic method to assess the PVR >150 ml with a 97.7% specificity and a negative predictive value of 89.5%, they concluded that the ultrasonic method is accurate enough to replace routine catheterization for the determination of PVR of >150 ml. In the present study, the repetition of ultrasound scan in patients who had the first scan volume ≤100 ml improved the specificity (97.2%), negative predictive value (100%) and accuracy (97.4%) in predicting the catheter volume ≤100 ml. The high rate of specificity, negative predictive values and the repetition of scans offer the possibility of using the 3D portable ultrasound for determining the PVR as an alternative to urethral catheterization.

In the present study, the incidence of urine retention (PVR >100 ml) in postoperative RH patients after the first spontaneous void was 40.0%, and declined to 28.6% on subsequent voiding. Saaby M[13] demonstrated the effect of repeatability of PVR measurement in urogynecologic patients, and found the prevalence of PVR >100 ml declined from 14% to 1.3% on repeated measurements. The prevalence of urinary retention among postoperative RH patients in the present study (28.6%) was comparable to the rate of 17 to 42% found in previous studies[1-3]. Urine retention is the most probably caused by the inevitable damage which occurs in the terminal branches of the pelvic plexus which innervate the urinary bladder and urethra. The difference of PVR in subsequent voiding may be due to diurnal change in bladder capacity at normal desire to void[14]. The voided volume influences the amount of PVR with a higher voided volume resulting in a higher PVR[15]. The diuretic effects of over hydration are well described[16]. It is important to measure the PVR immediately after voiding and prevent forcing of hydration on the day of catheter removal, especially in diabetic and hypertensive patients who are using diuretics. The repetition of PVR measurement on subsequent voiding to confirm consistency is recommended in clinical practice, as it not only decreases the need for re-catheterization but also safer for patients.

A limitation of the present study was interpersonal variation, although all staff nurses engaged in the study were well trained. As the same limitation is found in real practical settings, an intensive and regular training program is necessary to decrease interpersonal variation and improve the reliability of the measurements.

In conclusion, 3D portable ultrasound devices provide good correlation and high rates of specificity and negative predictive values, as well as acceptable accuracy in the assessment of PVR. Repetition of scan volume in subsequent voiding to confirm consistency improves reliability. These devices could be used as an alternative modality to catheterization for the measurement of PVR among postoperative radical

hysterectomy patients.

What is already known on this topic?

The incidence of urinary retention among postoperative radical hysterectomy with pelvic lymphadenectomy is 17 to 42% of cases.

The gold standard assessment of post-void residual urine volume (PVR) is bladder catheterization.

Several studies have assessed the accuracy of earlier generations of portable ultrasound devices (BVI 2000, BVI 2500, BVI 3000, and BioCon-500) in general urogynecologic patients.

What this study adds?

A newer 3D portable ultrasound device (Verathon BladderScan BVI 9400) demonstrated high correlation in the measurement of PVR when scan volumes were plotted against catheter volumes (number of measurements = 140, correlation coefficient = 0.89, $p<0.001$).

A 91.0% specificity and 93.1% negative predictive value (NPV) were obtained using the scan volume in predicting the catheter volume of ≤100 ml.

Repetition of ultrasound scan in patients who had a first scan volume of ≤100 ml yielded a 97.2% specificity and 100% NPV in predicting catheter volume of ≤100 ml.

The high rates of specificity, negative predictive values and the repetition of scans offers us the possibility of using the 3D portable ultrasound for determining the PVR as an alternative to urethral catheterization.

Acknowledgments

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Potential conflicts of interest

None.

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ความแม่นยำของการวัดปริมาตรปัสสาวะคงค้างด้วยเครื่องสแกนกระเพาะปัสสาวะ

คเณศร์ ธนกำธร

ภูมิหลัง: *ภาวะปัสสาวะคงค้างในผู้ป่วยหลังผ่าตัดมดลูกแบบถอนรากถอนโคนมีอุบัติการณ์ร้อยละ 17-42 การประเมินปริมาตรปัสสาวะคงค้างตามมาตรฐาน คือ การใช้สายยางสวนผ่านท่อปัสสาวะหลังจากที่ผู้ป่วยปัสสาวะเสร็จเพื่อตวงปริมาตรปัสสาวะที่สวนได้ ปัจจุบันได้มีการพัฒนาเครื่องสแกนกระเพาะปัสสาวะเพื่อใช้วัดปริมาตรปัสสาวะโดยใช้หลักการของอัลตราซาวด์สามมิติ*

วัตถุประสงค์: *เพื่อเปรียบเทียบความแม่นยำของการวัดปริมาตรปัสสาวะคงค้างด้วยเครื่องสแกนกระเพาะปัสสาวะกับการวัดโดยการตวงปัสสาวะที่ได้จากการสวนผ่านสายสวนท่อปัสสาวะ*

วัสดุและวิธีการ: *เป็นการศึกษาไปข้างหน้าในผู้ป่วยมะเร็งปากมดลูกที่ได้รับการผ่าตัดมดลูกแบบถอนรากถอนโคน หลังจากผู้ป่วยได้รับการถอดสายสวนปัสสาวะในวันที่ 7 ของการผ่าตัด ผู้ป่วยจะได้รับการดูแลให้ปัสสาวะภายใน 6 ชั่วโมง หรือให้ผู้ป่วยปัสสาวะได้เมื่อมีความรู้สึกปวดถ่าย ทันทีที่ผู้ป่วยถ่ายปัสสาวะเสร็จจะทำการวัดปริมาตรปัสสาวะคงค้างด้วยเครื่องสแกนกระเพาะปัสสาวะทำการบันทึกปริมาตรปัสสาวะที่วัดได้จากเครื่อง จากนั้นผู้ป่วยจะได้รับการสวนเก็บปัสสาวะผ่านสายสวนท่อปัสสาวะทันทีและทำการบันทึกปริมาตรปัสสาวะที่ได้ กระบวนการดังกล่าวจะทำซ้ำอีกหนึ่งครั้งในการปัสสาวะครั้งถัดไป นำข้อมูลปริมาตรปัสสาวะที่วัดได้จากเครื่องสแกนกระเพาะปัสสาวะและปริมาตรปัสสาวะที่วัดได้จากการสวนเก็บปัสสาวะผ่านสายสวนท่อปัสสาวะมาวิเคราะห์หาความสัมพันธ์*

ผลการศึกษา: *ผู้ป่วยจำนวน 70 ราย มีการวัดปริมาตรปัสสาวะคงค้าง 140 ครั้ง พบว่ามีความสัมพันธ์ของการวัดปริมาตรปัสสาวะคงค้างด้วยเครื่องสแกนกระเพาะปัสสาวะอยู่ในระดับสูง เทียบกับการวัดโดยการตวงปัสสาวะที่ได้จากการสวนผ่านสายสวนท่อปัสสาวะ ($r = 0.89$, $p<0.001$) การวัดปริมาตรปัสสาวะคงค้างด้วยเครื่องสแกนกระเพาะปัสสาวะมีความจำเพาะร้อยละ 91.0 ค่าทำนายผลลบร้อยละ 93.1 ในผู้ป่วยที่ปริมาตรจากการสวนเก็บปัสสาวะผ่านสายสวนท่อปัสสาวะ ≤100 มิลลิลิตร การวัดซ้ำด้วยเครื่องสแกนกระเพาะปัสสาวะในผู้ป่วยที่วัดปริมาตรปัสสาวะคงค้างด้วยเครื่องสแกนกระเพาะปัสสาวะครั้งแรก ได้ปริมาตร ≤100 มิลลิลิตร พบว่ามีความจำเพาะร้อยละ 97.2 และมีค่าทำนายผลลบร้อยละ 100 หากใช้ปริมาตรปัสสาวะคงค้าง >100 มิลลิลิตร เป็นเกณฑ์ในการสวนคาสายปัสสาวะ การวัดปริมาตรปัสสาวะคงค้างด้วยเครื่องสแกนกระเพาะปัสสาวะมีความแม่นยำร้อยละ 90.0*

สรุป: *การวัดปริมาตรปัสสาวะคงค้างด้วยเครื่องสแกนกระเพาะปัสสาวะมีค่าความสัมพันธ์ ค่าความจำเพาะและค่าทำนายผลลบที่สูงเทียบกับการวัดโดยการตวงปัสสาวะที่ได้จากการสวนผ่านสายสวนท่อปัสสาวะ การวัดปริมาตรปัสสาวะคงค้างด้วยเครื่องสแกนกระเพาะปัสสาวะเป็นทางเลือกในการวัดปริมาตรปัสสาวะคงค้างแทนการการวัดโดยการตวงปัสสาวะที่ได้จากการสวนผ่านสายสวนท่อปัสสาวะในผู้ป่วยมะเร็งปากมดลูกที่ได้รับการผ่าตัดมดลูกแบบถอนรากถอนโคน*