Noninvasive Bladder Volume Measurement

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ABSTRACT:The aim of this study was to compare the accuracy of bladder volume measurements using a portable ultrasound machine to measurement by catheterization. For 13 consecutive weeks, all patients admitted to the stroke unit at Royal Perth Hospital were studied by both methods when urinary retention was suspected. The accuracy of ultrasound bladder volume measurements and interobserver reliability were evaluated. Ninety ultrasound examinations were performed prior to catheterization, 70 were by one nurse, and 20 independently by two nurses. Correlation of ultrasound measurements with actual catheterized volume was highly significant (r=0.983) as was interobserver reliability. The study showed that noninvasive bladder volume measurements using ultrasound are safe, effective, inexpensive and a useful adjunct to preventive bladder management and continence management in stroke patients.

Introduction

Urinary retention in the stroke patient is a common problem, with the risk of overdistension of the bladder and subsequent bladder dysfunction.[7] Accurate bladder volume measurement in the presence of urinary retention following voluntary or involuntary voids is essential to identify potential overdistension of the bladder.

Bladder volume is usually measured by catheterization. Of all the catheterizations performed in stroke patients each month, we found a significant number of low volumes. These catheterizations could have been omitted if the urine volumes were measured accurately by a noninvasive method.[5] Avoidable catheterizations are those with post-void bladder volumes measured at or less than 100 ml. As the need to void does not usually occur at bladder volumes below 250 ml, catheterization can be delayed to allow trial voiding in cases of total urinary retention.

Catheterization is invasive and associated with the risk of urethral trauma and iatrogenic infection. Ultrasound measurement of bladder volume by a portable ultrasound scanner is noninvasive and has been proven to be safe.[1] The purpose of this study was to assess the accuracy of ultrasound measurements of bladder volume and to determine the interobserver variability in the measurements. The ultimate goal of the study was to reduce unnecessary catheterizations at residual bladder volumes below 100 ml and total bladder volumes below 250 ml. Both were to reduce the risk and discomfort to patients and save the cost of catheterization equipment and nursing time.

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Method

Patients

For 13 consecutive weeks, all patients admitted to the stroke unit at Royal Perth Hospital were enrolled in the study. A convenience sample of 22 female and 19 male participants was obtained. Informed consent was obtained either from the patient or the relatives. Patients had urinary retention related to cerebrovascular events, and required one of the following interventions:

- intermittent catheterization 3-4 times daily for complete urinary retention
- post-void residual catheterization according to degrees of bladder distension
- intermittent catheterizations as needed to check for retention following removal of an indwelling catheter and for those with unreliable bladder emptying secondary to medications or compromised cardiac and respiratory conditions

All patients were placed in the supine position for study as it was the most suitable position for the use of the ultrasound machine.

Estimation of Bladder Volume

An inexpensive, portable, AC-operated, real-time ultrasound scanning unit (MK100) was used to estimate bladder volume. It has an instrument box housing a displayed keyboard and function keys panel, a monitor for image display, an AC power line and a hand-held ultrasound transducer or scanhead.

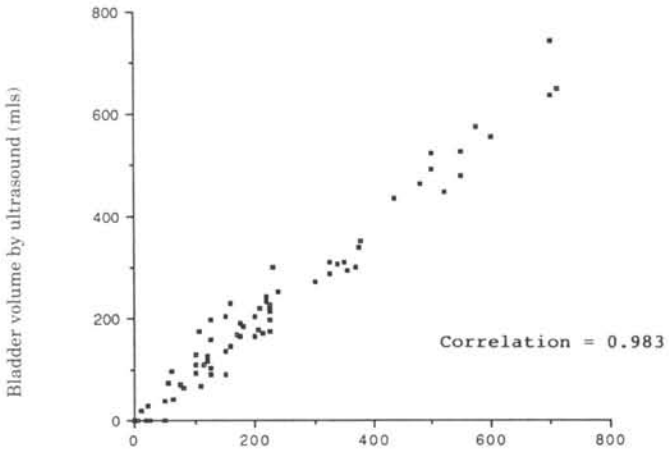

Fig 1. Scatter plot of raw data. Bladder volume as measured by ultrasound and urinary catheter.

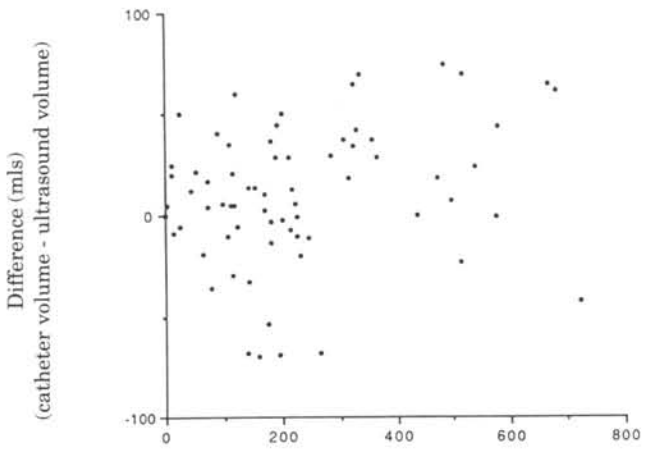

Fig 2. Plot of difference and average of bladder volume as measured by ultrasound and urinary catheter.

An accurate image of the bladder was obtained in the transverse and sagittal planes. Linear measurements of the following dimensions in both the sagittal and transverse views of the bladder image were recorded:

W - Width of transverse image
D1 - Anteroposterior dimension of the transverse image
D2 - Superior-inferior dimension of the sagittal image

The bladder volume was calculated based on the formula: W x D1 x D2 x 0.75 = bladder volume in ml. The correction factor of 0.75 was determined by the method of Birch, Hurst and Doyle.[1] With this technique comparison of ultrasound and catheterized volumes indicated that a correction factor of 0.75 was necessary.

Measurement Procedure

The participant was comfortably placed in the supine position, with the suprapubic area accessible and clearly visualized. A small amount of ultrasound translucent gel was applied to the skin in the midline and 3 cm above the pubis. The transducer was then placed lightly in contact with the skin to show the image of the bladder in the sagittal and transverse planes. Linear measurements of the dimensions in the largest sagittal and transverse images of the bladder were obtained and the bladder volume was calculated using the formula. The ultrasound gel was removed from the skin. The entire procedure was performed in less than 5 minutes in all cases. Following ultrasound, each participant's bladder was immediately emptied by urethral catheterization. The bladder volume as determined by ultrasound and catheterization was recorded.

Participating nurses from the stroke unit at Royal Perth Hospital received education on the principles of ultrasonography and operation of the portable ultrasound machine to measure bladder volume. The staff development nurse, responsible for teaching the skill, certified the nurses' competence in the technique after demonstrated accuracy in three consecutive supervised practices was obtained.[6]

Accuracy of the ultrasound estimation of bladder volume was determined by comparing ultrasound measurements with residual volume determined by catheterization immediately after ultrasound. To determine interobserver reliability ultrasound measurements were performed by the staff development nurse and another participating nurse within two minutes prior to catheterization. Twenty paired ultrasound measurements were recorded and compared with the catheterized volumes. Comparisons were then analyzed by the statistical methods as described by Bland and Altman, and Brennan and Silman.[2,3]

Results

Accuracy of Ultrasound Measurement

The 70 ultrasound measurements, ranging from 0-742 ml, were compared to catheterized volumes, which ranged from 0-710 ml. For ultrasound measurements versus catheterized volumes, a correlation coefficient of 0.983 (Fig 1) was produced by the statistical methods of Bland and Altman, Brennan and Silman.[2,3] The computed standard error mean of differences (catheterized volumes minus ultrasound measurements) was 4.05, the plot of difference and average of ultrasound measurements and

Table 1
Average Percentage Error by Ultrasound Estimations as Compared to Catheterized Volumes

Catheterized volume	Number < 100 ml (percent)	Number > 100 ml (percent)
≤100 ml (*N*=16)	13 (81.3%)	3 (18.7%)
>100 ml (*N*=54)	3 (5.6%)	51 (94.4%)
Average percentage error:	6/70 = 8.57%	

catheterized volumes (Fig 2) showed 95% of differences were within ± 2 standard deviation.[3] Raw data showed that ultrasound measurements were within 70 ml below to 60 ml above the catheterized volumes.

Of the 70 ultrasound measurements 16 were below 100 ml and 54 were above 100 ml. Out of the 16 catheterizations shown by ultrasound to be less than 100 ml, 3 catheterized volumes were above 100 ml, ie, 3 errors or an 18.7% error rate, had been found (Table 1). Of the other 54 in whom the ultrasound volumes were above 100 ml, 3 catheterized volumes were below 100 ml, ie, 3 errors or a 5.6% error rate (Table 1). If a clinical decision were to be made regarding catheterization according to ultrasound measurements above 100 ml, 6 errors would have been made for an 8.57% error rate.

Reliability

Repeated measurements and catheterized volumes by the staff development nurse revealed a correlation coefficient of 0.991 (Fig 3). In comparing measurements carried out by other nurses there was a correlation of 0.910 (Fig 4) between ultrasound measurements and catheterized volumes. In the 20 patients where ultrasound measurements were made both by the staff development nurse and another nurse, there was a correlation of 0.923 between the observers (Fig 5). The level of agreement between the staff development nurse and other nurses was good and showed no significant differences (Fig 6).

Discussion

Results of this study demonstrated that ultrasound estimation of bladder volume is not only safe and quick but also accurate. Bladder volume measurements by ultrasound provide an accurate assessment of the degree of bladder enlargement, thereby facilitating appropriate intervention to prevent bladder overdistension and unnecessary catheterization. Although we have confined our study to stroke patients, the ultrasound method has wide application in continence assessment and management of patients with other neurological and spinal disorders, incontinence secondary to other conditions and postoperatively, because of its noninvasive nature and measurement accuracy. We have used it with equal efficacy in patients with multiple sclerosis, Guillain Barré syndrome and spinal cord injuries.

Further, ultrasound measurement avoids the risks of urethral trauma and iatrogenic infection, is quite comfortable and preferred by patients to catheterization. This technique can also be used to provide noninvasive feedback to the patient and nurse on the effectiveness of continence strategies such as timed voiding programs, double voiding, suprapubic tapping, rectal stretch or medications (eg, prazosin, bethanechol).[5]

An obese abdomen, muscle spasm, ascites, abdominal herniation and abdominal breathing may interfere with scanning, and prevent accurate mea-

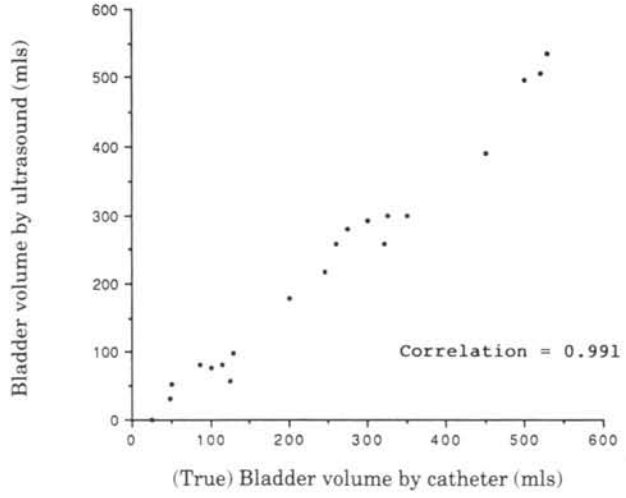

Fig 3. Correlation of ultrasound bladder volume with urinary catheter volume by the staff development nurse.

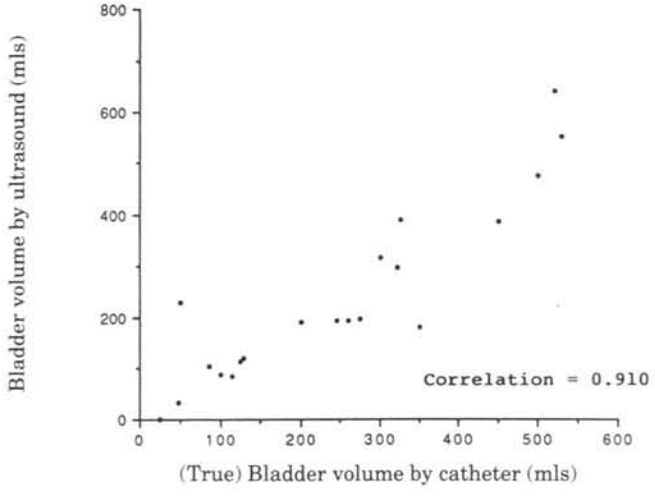

Fig 4. Correlation of ultrasound bladder volume with urinary catheter volume by the nurses.

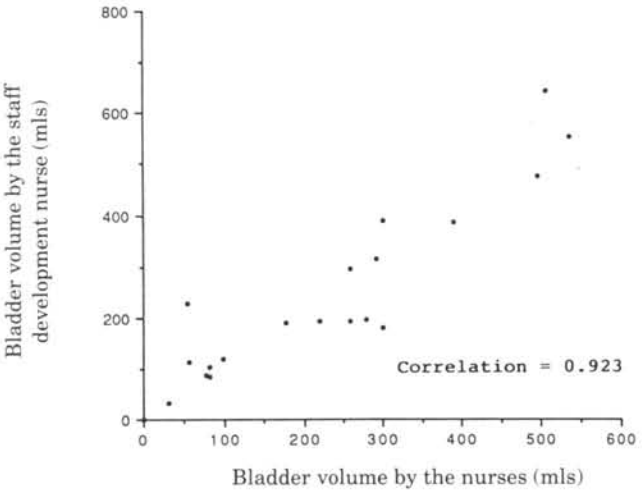

Fig 5. Correlation of ultrasound bladder volume measured by the staff development nurse and the nurses.

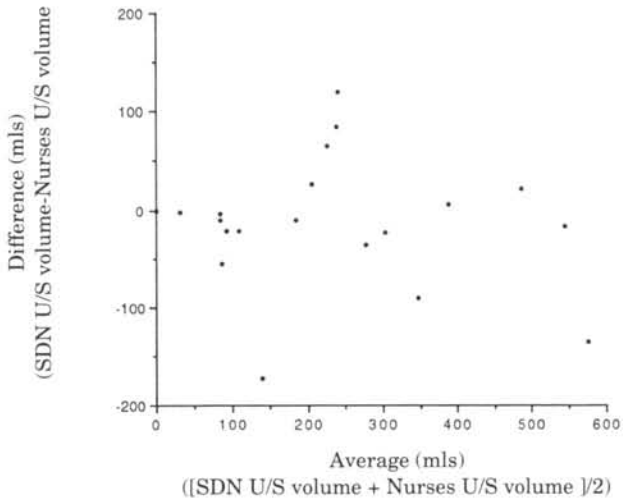

Fig 6. The plot of average and difference of ultrasound (U/S) bladder volumes by the staff development nurse (SDN) and the nurses.

surement. However we had experienced a slight difficulty only with measurements in two patients with obese abdomens in our study.

Our study results compare favorably with the modern portable BladderScan BVI2000 which has an 18% error rate on average.[5] Our study showed a clinical error rate of 8.57%. The high correlation of measurements taken by the staff development nurse compared to other nurses suggested that training and experience may further reduce the error rate.

The cost of the BladderScan BVI2000 is around $6000 Australian. Our portable ultrasound machine incurred no cost as it was no longer in clinical use. However, if the BladderScan BVI2000 is to be used, we believed that this method used with the bladder management program is still cost-effective in terms of patient comfort, decreased risks of trauma and iatrogenic infection, equipment cost and nursing time with a reduction in the number of unnecessary catheterizations. Our calculated savings were $1500 to $2000 Australian per month.

Summary

Ultrasound bladder volume measurement has proven to be an effective means of monitoring bladder overdistension. This study has shown that ultrasound estimation of bladder volume is not only safe and quick but also accurate. Our experience suggests that ultrasound bladder volume measurements are reliable for effective clinical decisions in bladder management. This technique may reduce unnecessary catheterizations with concomitant cost savings in equipment, nursing time and patient care.

Acknowledgment

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