Bladder Volume Determination: Portable 3-D Versus Stationary 2-D Ultrasound Device

Peter Schnider, MD, Peter Birner, MD, Alexandra Gendo, MD, Klaus Ratheiser, MD, Eduard Auff, MD


Objective: To investigate how accurately a portable three-dimensional (3-D) scanner and a multipurpose two-dimensional (2-D) real-time scanner determined bladder volumes.

Study Design: Prospective, controlled clinical trial, single-blind, crossover design.

Setting and Participants: Twenty-three inpatients with permanent bladder catheters participated voluntarily in this study.

Methods: The bladders of 20 patients were filled through an indwelling catheter with 60, 110, 160, 210, and 260mL sterile normal saline. Volumes were measured twice with each device. Measurements were compared with the actual bladder volumes.

Results: The 2-D device showed better reproducibility, particularly at lower bladder volumes. The 3-D scanner showed a significant difference between the two measurements at 160mL (p < .05) and had poor reproducibility at 110, 210, and 260mL. Both devices overestimated actual bladder volume at fillings of <160mL and underestimated it at fillings of ≥160mL. The range between the 25th and 75th percentiles was always larger for the 3-D scanner, except for the 210mL reading.

Conclusion: Both devices showed sufficient accuracy for clinical practice. Ultrasound measurements of >110mL should be followed by catheterization to detect potentially harmful bladder volumes.

Key Words: Bladder, neurogenic; Catheters, indwelling; Residual volume; Ultrasound; Rehabilitation.

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IN NEUROLOGIC REHABILITATION, consecutive measurements of residual urine volume are useful for monitoring bladder dysfunction, bladder retraining programs, and various drug effects. Urethral catheterization has been called the criterion method for determination of postvoid residual urine volume. Apart from discomfort, catheterization can be complicated by trauma and infection of the lower urinary tract, particularly in the inpatient setting. Furthermore, it has been shown that a certain volume of urine, which cannot be drained by a catheter, remains in the bladder after voiding. In neurologic rehabilitation, catheterization can be difficult because of behavioral disturbances and spastic contractures.

Some authors have suggested that sonographic bladder measurement should replace catheterization, whereas others have found ultrasound devices too inaccurate for clinical practice. Stationary, general purpose, real-time ultrasound devices are expensive and can only be operated by trained technicians. These devices are usually not available on neurologic wards. Portable 2-dimensional (2-D) scanners are sufficiently accurate for approximate determination of bladder volume, but improvement of these machines has been suggested. Recently a new generation of portable three-dimensional (3-D) scanners has been presented. To our knowledge, no data are available comparing measurements from two different ultrasound devices to actual bladder volumes, measured concurrently with the ultrasound.

METHODS

Patients. Twenty-three patients (12 men, 11 women), mean age 59.5yrs (SD, 14), were included in the study. Eighteen subjects had a preexisting bladder catheter after artificial respiration for medical reasons (6 hepatic failure, 1 acute respiratory distress syndrome, 5 recent myocardial infarction, 2 gastric and 4 neurosurgical operations). Five patients were catheterized because of urinary incontinence and intermittent loss of bladder sensation after major head trauma or cerebral ischemia. Informed consent was obtained from all patients after full written and oral explanation. The study was approved by the local ethics committee of the medical faculty of the University of Vienna.

Equipment. The portable 3-D scanner, used to determine bladder volume by volumetry as described by Marks, was a Bladderscan BV1 2500. The stationary ultrasound device used was a Vingmed CFM 800, which determined bladder volume by 2-D planimetry with the formula V = π ∫ t(x) dx according to Simpson.

Procedure. Before starting the ultrasound measurements, soft manual pressure was applied over the patient’s bladder to ensure complete urine drainage through the preexisting catheter. Bladder emptying was confirmed by a 3-D baseline measurement. The patient’s bladder was then filled through the catheter with sterile normal saline. Five fillings (50, 100, 150, 200, and 250mL) were performed in random order by a health care professional not associated with the study. The actual bladder volume was +10mL because the indwelling catheter’s balloon contained 10mL sterile saline. Each ultrasound device was operated by a trained physician blinded to the filling volume and to the results of the other device, which was operated by a different physician. Patients were in the supine position. Each investigator measured the bladder volume twice with the same device. The 3-D measurements were repeated if the display did not show the entire bladder on the scan. After the
The bladder was filled and the measurements were made, the bladder was emptied by means of the catheter, while soft manual pressure was applied to the lower part of the abdomen. When no more fluid was expressed (ie, when the drained volume consisted of the filled volume plus more than 10mL), the patient’s bladder was refilled and the procedure was repeated.

**Statistical analysis.** The Wilcoxon sign-ranked test was used to detect differences between the two measurements by one ultrasound device. The validity and range of measurements was calculated by median volume, standard deviation and 25th, 50th, and 75th percentiles. A computerized statistical program, SPSS 7.5, was used for all calculations.

**RESULTS**

### Failure of measurement with ultrasound.

In 3 of 23 patients, measurement with the 3-D device was not possible because of extreme tympanicity. These three patients were excluded from further investigation. In one patient, 2-D measurement of 110mL bladder volume could be performed only once because of an emergency in the same room with another patient. One patient withdrew consent without explanation during the study (bladder volume of 160mL could not be investigated). Another patient felt a very strong, unpleasant desire to urinate at 210mL and refused to have the bladder filled with 250mL.

All patients reported sensations with filling volumes of >60mL, but the sensations were not considered unpleasant except by the aforementioned patient.

### Reproducibility of measurements.

Results of the reproducibility of single measurements of residual urine volumes using the two devices are shown in Table 1. The 2-D device showed better reproducibility, particularly at lower bladder volumes. The portable 3-D scanner showed a significant difference between the two measurements at 160mL (p < .05) and rather poor reproducibility at 110, 210, and 260mL. We therefore decided to use the mean values (MVs) of the two measurements with one machine for further calculations.

### Validity of measurements.

Mean and median MVs compared with the target values (fig 1) show that at fillings of <160mL bladder volume was overestimated and at fillings of ≥160mL bladder volume was underestimated with both devices, when the mean MVs and the median MVs with the 3-D device were calculated. Actual bladder volume was always underestimated with the 2-D device when using the median MVs.

### Range of measurements.

Except for the 210mL reading, the range between the 25th and 75th percentiles was larger for the 3-D device. However, the range between the minimum and maximum values measured was larger for the 2-D device because of numerous peripheral values.

### DISCUSSION

Various studies have assessed the clinical utility of ultrasound measurements in determining bladder volumes.1,2,8-11 To our knowledge no data are available comparing measurements from 2-D and 3-D technologies in comparison to actual bladder volumes taken concurrently with the ultrasound. Before our study, the tested portable 3-D scanner had only been used in a study by Marks and colleagues7; a previous version was used in a study by Coombes and associates.1 In our study, measurements made with the 2-D device were more reproducible than...
those obtained with the 3-D device and did justice to the role of a multipurpose stationary machine. However, our data are in contrast to those of Marks,7 who had more accurate and reliable results with 3-D volumetry than with fixed-formula methods. In the present study, both 2-D and 3-D devices overestimated bladder volumes at lower fillings and underestimated volumes at higher fillings. Marks7 documented general underestimation, although differentiation between low and high bladder volumes was not calculated.

Accurate determination of bladder volume with an indwelling catheter would be useful in bladder training and in the determination of bladder sensitivity; however, it has been suggested that invalid sonographic measurements result in the escape intermittent catheterization would have been 160mL. Withholding one single episode of intermittent catheterization on a patient with a urine volume of 260mL would likely cause little harm.

CONCLUSION

We conclude that both the portable 3-D and the stationary 2-D ultrasound scanners are sufficiently accurate for clinical practice. A wide range of measurements suggests that mean values should be calculated for more reliable results. Ultrasound measurements of >110mL should be followed by catheterization for detection of potentially harmful bladder volumes.

References


Suppliers
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