

RELIABILITY OF INTRABLADDER PRESSURE MEASUREMENT IN INTENSIVE CARE

By Melanie Horbal Shuster, PhD, APRN-BC, Tammy Haines, RN, BSN, L. Kathleen Sekula, PhD, APRN-BC, John Kern, PhD, and Jorge A. Vazquez, MD

CE 1.0 Hour

Notice to CE enrollees:

A closed-book, multiple-choice examination following this article tests your understanding of the following objectives:

1. Describe the importance of establishing reliability of intrabla dder pressure (IBP) measurements in critically ill patients.
2. Identify the factors that affect IBP measurements.
3. Discuss the nursing implications associated with obtaining accurate intra-abdominal pressure (IAP) and IBP measurements in critical care patients.

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Background The reliability of intrabla dder pressure measurements obtained in nonsupine patients is unknown.

Objectives To investigate the reliability of measurements of intrabla dder pressure obtained with 30° head-of-bed elevation.

Methods With patients supine, 30° head-of-bed elevation, and instillation of 0 and 25 mL physiological saline, intrabla dder pressure was measured in 10 patients: twice by one nurse to assess intraobserver reliability and once by a different nurse to assess interobserver reliability. Data were analyzed by using paired *t* tests, Pearson correlation, and Bland-Altman analysis.

Results For intraobserver reliability, measurements obtained with no instillation (mean difference, -1.8; 95% confidence interval [CI], -4.9 to 1.3; *P* = .22) and with instillation of 25 mL (mean difference, -0.6; 95% CI, -1.8 to 0.6; *P* = .28) did not differ significantly. Pearson *r* values were 0.74 and 0.81, respectively. Estimated Bland-Altman bias and limits of agreements were -1.8 and -10.3 to 6.7 mm Hg and -0.6 and -3.82 to 2.62 mm Hg, respectively. For interobserver reliability, measurements obtained with no instillation (mean difference, 1.0; 95% CI, -2.2 to 4.2; *P* = .49) and with instillation of 25 mL (mean difference, -0.7; 95% CI, -2.45 to 1.05; *P* = .39) did not differ significantly. Pearson *r* values were 0.78 and 0.82, respectively. Estimated Bland-Altman bias and limits of agreement were 1.0 and -7.76 to 9.76 mm Hg and -0.7 and -5.5 to 4.0 mm Hg, respectively.

Conclusions Reliability of intrabla dder pressure measurements obtained with 30° head-of-bed elevation is strong. (*American Journal of Critical Care*. 2010;19:e29-e40).

Using measurement of intra-abdominal pressure (IAP) in critically ill patients to monitor for intra-abdominal hypertension and to detect abdominal compartment syndrome is increasingly recommended by experts.¹ Routine measurement of IAP is advocated as an integral part of monitoring. Because direct measurement in intensive care units (ICUs) is difficult, IAP is usually estimated indirectly by measuring intrablower pressure (IBP)² as initially described by Kron et al.³

The method of Kron et al is based on the principles of hydrostatic pressure. Briefly, IBP is transmitted through a fluid-filled urinary catheter connected by external tubing to a pressure transducer. In order to ensure that the catheter is filled at the time of measurement, physiological saline is instilled into the bladder before the measurement is taken. The transducer converts the pressure into an electrical signal that is amplified and displayed on the bedside monitor as a waveform and digital value. However, for accurate IBP measurements, the transducer must be leveled to an anatomic landmark that reflects the bladder and be zeroed appropriately.

Because the principles, technique, and equipment of IBP measurements are similar to those used for hemodynamic measurements,^{4,7} most likely many ICU nurses have the basic skills for leveling and zeroing the pressure transducer, performing square wave testing, identifying pressure waves, and recording numeric values necessary for accurate measurements.^{7,8} However, formal education on the principles of hydrostatic pressure and hemodynamic monitoring does not ensure that the knowledge and skills acquired are translated into clinical practice.^{5,9,10}

IBP measurements obtained by ICU nurses can be used by clinicians to guide surgical therapy such as laparotomy for abdominal decompression and drainage of intra-abdominal fluid collections or medical therapy such as optimization of fluid administration, gastrointestinal suction, and neuromuscular

blockade.¹¹ For IBP measurement to become a universal diagnostic tool and a common guide for therapy, the measurements must be reliable.

Intraobserver and interobserver reliabilities of IBP measurements obtained by ICU nurses have not been reported. Only a single research study¹² in which intraobserver and interobserver reliabilities of IBP measurements were determined in critically ill patients who were supine with no elevation of the head of the bed has been published in English. Positioning patients supine solely for IBP measurements places the patients at risk for aspiration and the possibility of pneumonia, increases their discomfort, and increases the workload of ICU nurses. Therefore, measuring IBP with patients in a position that meets current practice guidelines and recommendations is preferred. The aim of our study was to assess the intraobserver and interobserver reliabilities of IBP measurements obtained in the ICU with patients supine and the head of the bed elevated 30°.

Intra-abdominal pressure can be estimated by measuring intrablower pressure.

Methods

A prospective, nonexperimental, 2-observer repeated measures (between and within) study design was used. With patients supine, a 30° head-of-bed elevation, and instillation of 0 and 25 mL of physiological (normal) saline, IBP was measured in 10 patients, twice by one nurse to assess intraobserver reliability and once by a different nurse to assess interobserver reliability. The 25-mL volume was chosen to represent the recommendation of the World Society of Abdominal Compartment Syndrome (WSACS).¹³ The 0-mL volume was chosen because in studies¹⁴ in humans, this volume was associated with a lower measurement bias and the lowest risk of raising urinary bladder pressure independently of IAP. In addition, not instilling saline would be most convenient for nurses.

The 2 sets of IBP measurements obtained by the first nurse were used to determine intraobserver

About the Authors

Melanie Horbal Shuster is a nutrition clinical nurse specialist, at the time of the study **Tammy Haines** was a research coordinator, and **Jorge A. Vazquez** is director of medical nutrition at the West Penn Allegheny Health System, Allegheny Center for Digestive Health, Pittsburgh, Pennsylvania. **L. Kathleen Sekula** is an associate professor at Duquesne University, School of Nursing, and **John Kern** is an associate professor of statistics in the department of mathematics and computational science at Duquesne University in Pittsburgh.

Corresponding author: Melanie Horbal Shuster, RN, PhD, 1307 Federal St, Ste 301, Pittsburgh, PA 15212 (e-mail: mshuste1@wpahs.org).

reliability. The second set obtained by the first nurse were compared with the set of measurements obtained by the second nurse to determine interobserver reliability. Reliability was defined as consistency, stability, and repeatability of results¹⁵ as well as the ability to reproduce and record the same or similar IBP measurements at 2 different times by one or more observers (within a 30-minute period) when a standardized protocol was used. The study was approved by the institutional review boards of the Allegheny Singer Research Institute and Duquesne University, Pittsburgh, Pennsylvania, and was carried out in accordance with the ethical standards set forth in the Helsinki Declaration of 1975. Each patient or a designated surrogate gave written informed consent.

Setting

The study was performed in a 700-bed tertiary care hospital designated as a level I trauma center that has 105 adult ICU beds segregated as either surgical units (trauma, neurological, cardiothoracic, and surgical) or medical units (neurological, medical, and cardiac). Collectively these units are staffed by more than 325 ICU nurses; 10% of the nurses have national specialty certifications.

Sample

Adult patients admitted to one of the ICUs were eligible to participate in the study if they had a clinical need for a urinary bladder drainage catheter as determined by the attending physician. Patients

were excluded from the study if they could not assume a supine position with the head of the bed elevated 30° or if they had a neurogenic bladder, bladder tumor or perforation, or hematuria or anuria, all of which can potentially alter IBP and influence interpretation of IBP measurements. Participation in the study was required only once during the ICU stay.

IBP Measurements

IBP was measured according to a standardized protocol (Table 1). The method was initially described by Kron et al³ and was modified by Cheatham and Safcsak¹⁶ and Malbrain.¹⁷ The only difference between the modified method of Kron et al and the protocol used in this study was use of the AbViser IAP monitoring kit (Model ABV100, Wolfe-Tory Medical, Inc, Salt Lake City, Utah). Physiological saline was used as the instillation fluid and was kept at room temperature during the study. During the measurements, the urinary catheter (Foley, CR Bard Inc, Gainesville,

Virginia) lay on the ICU bed between the patient's legs with the drainage collection tubing flat until the tubing was beyond the patient's feet; the drainage collection chamber was suspended from the bed frame. The IBP was recorded from the bedside monitors (HP Model 66, Hewlett Packard, Royal Phillip Electronics, Eindhoven, the Netherlands) at end expiration after 2 full screen sweeps of a stable waveform were observed.

A laser level (Model 9-00085887, Porter-Cable Robotoolz; Toolz, Mountain View, California) was used to level the pressure transducer at the symphysis pubis.¹⁸ The symphysis pubis was chosen as the reference point because it was the reference point recommended by the American Association of Critical-Care Nurses (AACN)⁴ and the WSACS¹⁷ at the time the study was designed, and because it was the reference point used in previous assessments of the reliability of IBP measurements.¹² The only difference between the first set of measurements and the second and third sets was that the AbViser was not removed after the first set. The device was kept in place to maintain a closed system and to reduce the risk of infection. Between the first and second set of measurements, the first nurse relevelled and rezeroed the pressure transducer and verified the patient's position. Before the third set of measurements, the second nurse confirmed the patient's position, relevelled the transducer at the symphysis pubis, performed a manual square wave test to ensure the dynamic properties of the system were maintained and that conduction of pressure from the catheter to the monitor occurred, and then rezeroed the transducer.

Statistical Analysis

Data were analyzed by using SPSS statistical software (SPSS-15, SPSS Inc, Chicago, Illinois), and figures were created by using Prism 4 (Version 4.03, GraphPad Software Inc, San Diego, California). Continuous data were expressed as means and standard deviations and were analyzed by using paired *t* tests, Pearson correlation, and the Bland-Altman method for comparison with the limits-of-agreement approach.¹⁹ The Bland-Altman plot graphs the difference between 2 measurements as a function of the mean of 2 measurements for each participant, which is considered to be the best estimate of the true value of the measurement. Bias is the difference between one measurement and the other. If the first measurement is sometimes higher and the second measurement is sometimes higher, then the mean of the difference should be close to zero. The closer the bias is to 0, the lower the variability and the

A laser level was used to level the pressure transducer at the symphysis pubis.

Table 1
Protocol for bedside measurement of urinary bladder pressure

Step ^a	Action
1	Ensure that a bedside monitor with electrocardiographic, respiratory, and pressure monitoring capabilities is available and functional
2	Position the patient supine with the head of the bed elevated 30°
3	Open the AbViser intra-abdominal pressure monitoring kit. Using sterile technique, assemble the kit and attach it according to the manufacturer's directions. (See http://www.wolfetory.com/abviser.php .)
4	Place the catheter between the patient's legs and place the drainage tubing flat on the bed. When the tubing is beyond the patient's feet, suspend the collection bag to either the right or left side of the bed frame to prevent any increase in elevation of the collecting system or compression of the catheter or collecting system
5	Using a laser level, level the transducer with the symphysis pubis
6	Zero the transducer by opening the stopcock to air and selecting the zero option on the monitor
7	Assess the responsiveness of the monitoring system <ul style="list-style-type: none"> • Perform a manual square wave test: close the stopcock to the patient and inject saline against the transducer • Observe a square wave on the monitor
8	Assess the conductivity of the fluid-filled column <ul style="list-style-type: none"> • Squeeze the urinary drainage catheter proximal to the connection of the AbViser • Observe a pressure inflection on the bedside monitor
9	With no urine in the collection tubing, clamp the urinary collection tubing with a hemostat distal to but as close as possible to the AbViser for the first measurement of intrabladder pressure
10	Empty the urimeter and enter the amount of urine on the output record
11	Record the first intrabladder pressure of the first set from the monitor at the end of expiration and ensure that urine has filled the AbViser chamber
12	Unclamp the urinary drainage catheter distal to the AbViser valve by releasing the hemostat, and allow the bladder to drain for 30 to 60 seconds <i>Note the amount of urine that drains into the urimeter, record the amount on the output record, and empty the urimeter</i>
13	Using the syringe, inject 25 mL of normal saline into the bladder
14	Record the second measurement of intrabladder pressure of the first set from the monitor at the end of expiration
15	The AbViser valve will automatically open to permit drainage <i>Note that the amount of drainage in the urimeter is 25 mL or more</i>
16	Document the instilled volume on the intake record and the drainage on the output record
17	Confirm that the patient is supine with the head of the bed elevated 30°
18	Using a laser level, level the transducer with the symphysis pubis again, and rezero the monitor
19	Repeat steps 9 and 10
20	Record the first measurement of intrabladder pressure of the second set from the monitor at the end of expiration and ensure that urine has filled the AbViser chamber
21	Repeat step 12
22	Document the instilled volume on the intake record and the amount of drainage on the output record
23	Inject 25 mL of normal saline into the bladder
24	Record the second measurement of intrabladder pressure of the second set from the monitor at the end of expiration
25	The AbViser valve will automatically open to permit drainage. <i>Note that the amount of urine and saline that drain into the urimeter is 25 mL or more and record the amount on the output record and empty the urimeter</i>
26	Repeat steps 2 and 4 to 16, except for steps 11 and 14 because these 2 steps will be the first and second measurements of the third set, respectively.

^a Steps 1-24 are performed by one nurse, and then another nurse performs step 26.

higher the reliability. If the bias is not close to 0, the 2 measurements are not similar. Sample size was calculated by using PASS (Number Cruncher Statistical

Software, Kaysville, Utah, published April 23, 2007). A sample size of 10 had a 97% power to detect a difference of 0.8 between the null hypothesis correlation

Table 2
Characteristics of the sample

Sex	Age, y	Body mass index ^a	Length of stay, d	Reason for admission to the intensive care unit
Male	77	22.3	8	Abdominal wall dehiscence after colon resection
Female	72	28.4	1	Fall with subarachnoid bleeding
Male	81	21.1	5	Exacerbation of chronic obstructive pulmonary disease
Male	86	29.5	4	Osteomyelitis after laminectomy
Male	67	37.5	3	Colon cancer after proctosigmoid resection with loop ileostomy
Female	79	33.2	3	Pancreatic cancer after Whipple procedure with gastrostomy
Female	78	20.3	2	Fall with right temporal, occipital, and parietal hemorrhages
Female	80	21.7	1	Strangulated hernia after exploratory laparotomy with small-bowel resection
Male	63	35.2	1	Fall with fractured ribs and splenic laceration
Male	75	33.2	5	Thoracic aneurysm after thoracotomy with surgical repair
Mean (SD)	75.8 (6.8)	28.2 (6.4)	3 (2)	
Range	63-86	20-37	1-8	

^a Calculated as weight in kilograms divided by height in meters squared.

of 0.9 and the alternative hypothesis correlation of 0.1 with a 2-sided hypothesis test with a significance level of 0.05.

Results

Description of the Sample

A total of 6 men and 4 women took part in the study (Table 2). Of these 10 patients, 5 were admitted to the ICU for medical reasons and 5 for postoperative care; 3 of the 5 postoperative patients had had abdominal surgery. No patients were paralyzed or receiving mechanical ventilation, but 2 were treated with positive airway pressure during the study. Of the 10 patients, 1 was receiving enteral nutrition, 4 were not permitted anything by mouth, 1 was permitted ice chips, and 4 were permitted regular oral intake.

Intraobserver Reliability

When no physiological saline was instilled into the bladder, the first IBP measurement ranged from -5 to 12 mm Hg. Of the 10 patients, 8 had positive values, 1 had a value of 0 mm Hg, and 1 had a value of -5 mm Hg. The second IBP measurement ranged from -4 to 14 mm Hg; compared with the first measurement, the second was higher for 6 patients and lower for 4 (Figure 1). The patient with the negative value for the first measurement also had a negative value for the second measurement. The means of the first and second measurements were 6.1 (SD, 5.9) and 7.9 (SD, 6.1) mm Hg, respectively. Pearson correlation of the 10 pairs of measurements was 0.74 ($P = .007$). The mean of the difference was -1.8 (95% confidence interval, -4.9 to 1.3; $P = .22$).

When 25 mL of saline was instilled, the first measurements ranged from 7 to 16 mm Hg and the second measurements ranged from 10 to 18 mm Hg. The second measurements were higher than the first in 5 patients, lower in 3 patients, and the same in 2 (Figure 1). The means of the first and second measurements were 12.1 (SD, 2.7) and 12.7 (SD, 2.7) mm Hg, respectively. Pearson correlation between the 10 pairs of measurements was 0.81 ($P = .002$). The mean of the differences was -0.6 (95% confidence interval, -1.8 to 0.6; $P = .28$).

When the IBP measurements were obtained with no instillation of saline, the bias of the estimated measurements was -1.8 mm Hg (Figure 2). The limits of agreement or the expected difference between measurements of future samples was between -10.3 and 6.7 mm Hg. When the IBP measurements were obtained after instillation of 25 mL of saline, the bias of the measurements was -0.6 mm Hg, and the limits of agreement were between -3.82 and 2.62 mm Hg; both values (bias and limits of agreement) are lower than those for the set of measurements obtained with no saline.

Interobserver Reliability

When no saline was instilled into the bladder, the second nurse obtained IBP measurements that were the same in 2 patients, lower in 4 patients, and higher in 4 patients than the values obtained by the first nurse (Figure 3). The patient with the lowest IBP value obtained by the first nurse also had the lowest value of the 10 patients when IBP was measured by the second nurse. IBP values ranged

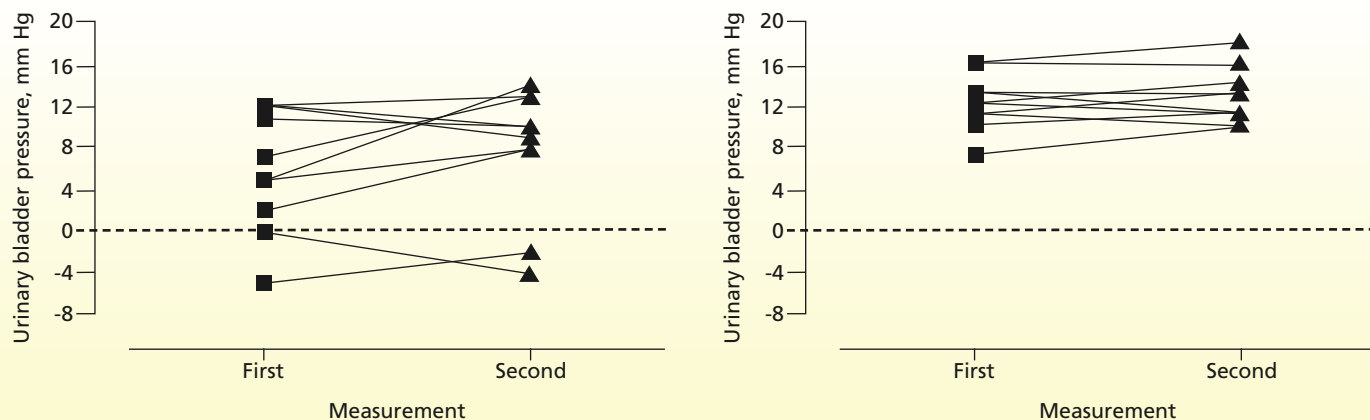


Figure 1 Individual values for measurements of intrablower pressure obtained by the first nurse with 0 mL (left) and 25 mL (right) of physiological saline instilled into the bladder. By paired *t* tests, *P* values were .20 (left) and .30 (right).

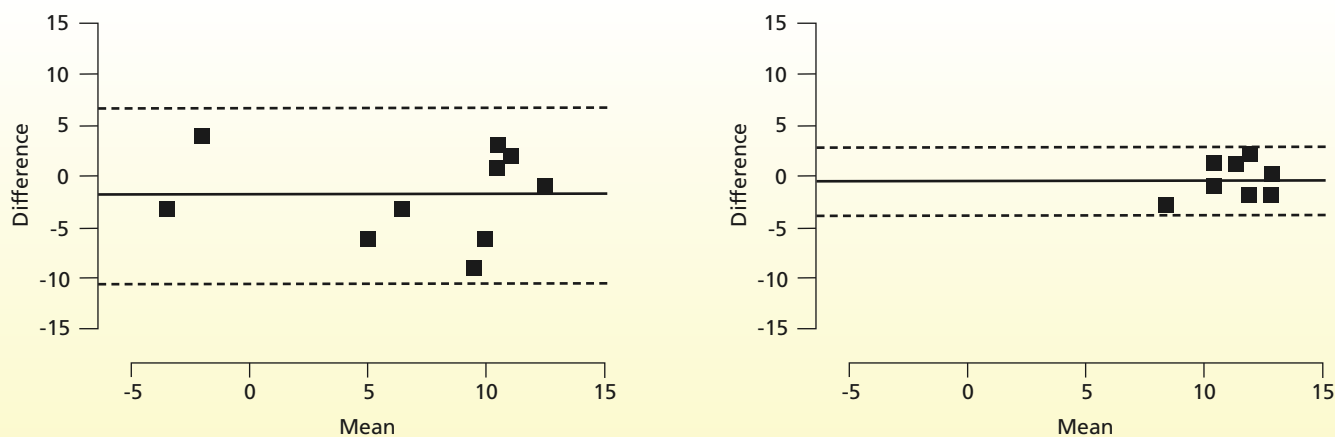


Figure 2 Bland-Altman plot for the paired intrablower pressure measurements obtained by the first nurse with 0 mL (left) and 25 mL (right) of physiological saline instilled into the bladder. The solid line represents the bias; the dotted lines, the limits of agreement.

from -4 to 14 mm Hg for the first nurse and from -3 to 16 mm Hg for the second nurse. The means of the IBP measurements were 7.9 (SD, 6.1) for the first nurse and 6.9 (SD, 7.1) mm Hg for the second nurse. Pearson correlation between the 10 pairs was 0.78 ($P = .004$). The mean of the differences was 1.0 (95% confidence interval, -2.2 to 4.2; $P = .49$).

When 25 mL of saline was instilled, compared with the first nurse, the second nurse obtained IBP measurements that were higher in 5 patients, lower in 4 patients, and the same in 1 patient. The measurements ranged from 10 to 18 mm Hg for the first nurse, and 8 to 20 mm Hg for the second nurse. The means were 12.7 (SD, 2.7) mm Hg for the first nurse and 13.4 (SD, 4.1) mm Hg for the second nurse. The Pearson correlation between the 10 pairs was 0.82 ($P = .002$). The mean of the differences was -0.7 (95% confidence interval, -2.45 to 1.05; $P = .39$).

When IBP was measured without instillation of saline, the bias of the measurement was 1.0 and the limits of agreement were between -7.76 and 9.76 mm Hg. When IBP was measured after instillation of with 25 mL of saline, the bias of the measurement was -0.7 mm Hg and the limits of agreement were between -5.5 and 4.0 mm Hg (Figure 4).

Discussion

Our findings indicate that both intraobserver and interobserver reliabilities of measurements of intrablower pressure are strong when IBP is measured with patients supine, the head of the bed elevated 30°, and an instillation volume of either 0 or 25 mL is used. However, compared with no instillation of saline, instillation of 25 mL reduced the variability of repeated measurements and increased the reliability.

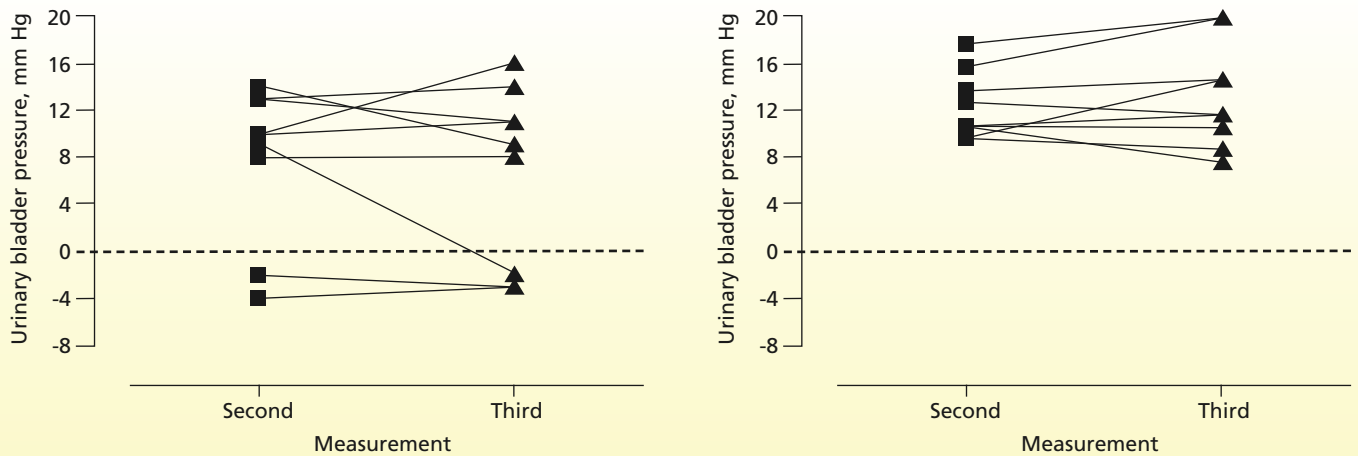


Figure 3 Intrablander pressure measurements taken by the first nurse and the second nurse after instillation of 0 mL (left) and 25 mL (right) of physiological saline into the bladder. By paired *t* tests, *P* values were .50 (left) and .90 (right).

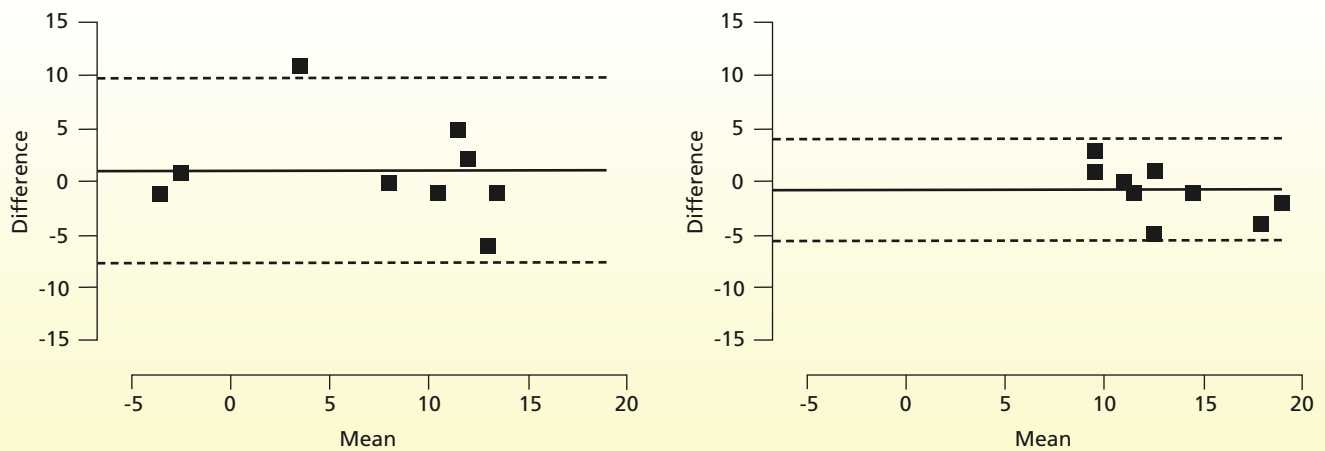


Figure 4 Bland-Altman plot for paired intrablander pressure measurements taken by the first nurse and the second nurse after instillation of 0 and 25 mL of physiological saline into the bladder. The solid lines represent the bias; the dotted lines, the limits of agreement (*n* = 10).

Our results agree with those of 1 experimental²⁰ and 1 clinical¹³ study on the reliability of IBP measurements. Wolfe and Kimball²⁰ built a laboratory model of the abdomen by using a 210-L container with a urinary catheter exiting from the base of the container. The proximal end of the urinary catheter tip was sealed with a 100-mL bag and was placed at the base of the container, simulating a urinary bladder, and the distal end was connected to the AbViser system and a pressure transducer, which was connected to the monitor. The pressure transducer was leveled and zeroed at the level of the simulated bladder at the base of the container. A column of fluid was placed within the container to simulate IAPs of 5, 10, 15, 20, 25, 30 and 40 mm Hg. A total of 11 observers each obtained 5 measurements for each of the 7 simulated IAPs. Wolfe and Kimball found little interobserver variability of the measurements

and the standard deviations of the measurements were small (0.1-0.5). In that study,²⁰ Wolfe and Kimball assessed variability of the monitoring system but did not address more important questions such as variability introduced by patients or by the technique of the ICU nurses.

The intraobserver and interobserver reliabilities of IBP measurements obtained after instillation of 25 mL of saline in our study agree with those in the study by Kimball et al,¹² the only other study in which the reliability of IBP measurements was assessed by using a technique and clinical setting similar to the ones we used. Both studies indicated no difference between the mean IBP values and a high Pearson correlation for intraobserver and interobserver reliabilities. In the study by Kimball et al,¹² the Pearson correlation for paired samples for IBP measurements obtained after instillation of 50 mL

of saline was slightly higher than in our study for measurements obtained after instillation of 25 mL (0.93 vs 0.81 for intraobserver reliability and 0.95 vs 0.82 for interobserver reliability, respectively), and their mean difference was lower (0.57 vs -0.6 mm Hg for intraobserver reliability and 0.00 vs -0.7 mm Hg for interobserver reliability, respectively). Nonetheless, both Kimball et al and we found low variability and high intraobserver and interobserver reliabilities.

The slightly higher intraobserver and interobserver correlations in the study by Kimball et al¹² might be due to 3 important differences in the experimental design. First, Kimball et al measured IBP with patients supine, the head of the bed unelevated, and instillation of 50 mL of saline. We obtained IBP measurements with patients supine, the head of the bed elevated 30°, and instillation of 0 and 25 mL of saline. These differences are important because a marked position-volume interaction can affect measurements of IBP. For instance, in a larger study,²¹ when participants were positioned supine, IBP measured after instillation of 50 mL of saline was higher than when 25 mL was instilled, but when the participants were positioned supine with the head of the bed elevated 30°, the opposite occurred. IBP measured after instillation of 50 mL was lower than the IBP measured after instillation of 25 mL.

Second, the technique of establishing the reference point for zeroing and leveling the pressure transducer differed. In the study by Kimball et al,¹² the transducer remained fixed at the symphysis pubis and was not relevelled or rezeroed between IBP measurements. In our study, the pressure transducer was relevelled and rezeroed, and the entire monitoring system was rechecked and a square wave test was performed between IBP measurements obtained by the first nurse and those obtained by the second nurse. Thus, the paired-sample data obtained in our study not only reflect the variability due to the administration of saline, reading the monitor, and the condition of the participant but also include the variability due to differences in the process used to measure IBP, such as transducer positioning, leveling, and square wave testing between ICU nurses. Last, Kimball et al¹² had a larger study population (18 patients) than we did (10 patients) and a larger sample size (18 vs 10 paired samples).

However, in the study by Kimball et al,¹² from 1 to 39 paired samples per patient were used for analysis, and some of the paired samples were excluded because they exceeded the collection time. Having few subjects contribute a large number of the sample data points and omitting data from the analysis will bias the data toward lower variability

and higher correlation. In contrast, we had 10 patients, with 3 pairs of measurements per patient, and no pairs were omitted from the analysis.

Factors Affecting IBP Measurements

The reliability of an IBP measurement is a function of the several factors that may affect the measurement, such as the accuracy of the equipment, the technique of the nurse or observer, and other patient-related clinical factors. Previous investigators^{5,22} have shown that when properly calibrated, bedside monitoring equipment, as used in our study, is sensitive and produces a reliable transduction of hydrostatic pressures. Some of the most pertinent patient-related factors are body weight,²³ use of sedatives,²⁴ breathing and ventilatory status with positive airway pressure,²⁵ net fluid balance,²⁶ and body position.²⁷ The patients in our study had a mean body mass index of 28.2 and a mean length of stay of 3 days and were not sedated or treated with mechanical ventilation, characteristics that may partly explain the low variability of our results.

Factors related to a nurse's technique that can contribute to variability in IBP measurements include the accuracy in positioning the patient, proper assembly of the equipment (ie, ensuring no air bubbles are present in the tubing, placing and leveling the transducer properly, and zeroing the pressure transducer), proper identification of the waveform, and reading the monitor at end expiration.⁵ Because ICU patients are usually extremely ill and are receiving multiple therapies, patient-related factors are difficult to standardize and would be expected to contribute markedly to the variability of paired IBP measurements.

Technical Skills of Nurses

Among the potential factors contributing to variability in IBP measurements, the technique nurses use is an area of focus to limit variability. Our findings indicate that variability in IBP measurements is low when the nurses' technique is standardized. We standardized the technique by using an ICU bed that allowed accurate elevation of the head of the bed to 30°, using a laser level to level the pressure transducer at the symphysis pubis before zeroing for all measurements, using the AbViser system instead of stopcocks or needles inserted into the sampling port of the urinary drainage system to reduce the risk of infections and technical variability, and keeping the urinary drainage collection

Both intraobserver and interobserver reliabilities of measurements of intrabladder pressure are strong.

tubing on the bed until the tubing was beyond the patient's feet and then suspending the tubing from the bed frame.

Recommendations for Volume of Saline Instilled

WSACS¹ and AACN⁴ recommend that IBP be measured after instillation of 25 mL and 50 mL, respectively of physiological saline. Recent studies^{1,28,29} have indicated that in supine patients increases in the volume of saline instilled result in progressive increases in IBP. The main explanation²⁹ for these findings is that a high volume has a higher probability than a lower volume of activating the bladder detrusor muscle and of affecting bladder compliance. Because of the potential for activation of the detrusor muscle, several investigators have advocated the use of a minimal volume to ensure conduction of the fluid wave.³⁰ Our findings indicate that reproducible IBP measurements can be obtained without instilling any sterile saline into the bladder.

However, most patients in the ICU are receiving continuous intravenous fluids, and most likely small amounts of urine would be in the bladder at the time of measurement. In addition, the bladder probably would not be completely empty even when drained.

During our study, the presence of urine became apparent when the drainage collection tubing was clamped for the first IBP measurement and urine filled the AbViser,

the drainage collection tubing, and the catheter within seconds of clamping and immediately before the time of measurement of IBP.

Compared with instillation of 25 mL of saline, instillation of no saline resulted in greater variability in IBP measurements and occasional subatmospheric (negative) values, and mean IBP was 6 mm Hg lower (Figures 1 and 3). Subatmospheric IAPs have been measured in previous studies³¹ in animals and cadavers but not in clinical studies,^{12,29,30,32,33} perhaps because volumes from 10 to 250 mL were instilled into the bladder. Our results agree with those of DeWaele et al,³⁰ who reported that up to 76% of the time a fluid wave could be detected when no saline was instilled and that 2 mL was adequate to ensure fluid wave transmission for the remaining cases. On the basis of our results and the results of others,³⁰ measuring IBP without instillation of saline should be avoided.

In our study, the saline instilled into the bladder was at room temperature (22°C). Recently, Chiumello et al³⁴ found that instilling normal saline

into the bladder at room temperature results in slightly higher values than does instilling the same amount of normal saline at body temperature (37°C). This effect was more pronounced with high volumes. A possible explanation³⁴ is that room-temperature saline injected into the bladder can activate the detrusor muscle. The validity of the explanation is questionable; the bladder cooling reflex occurs only in infants and young children and in patients with abnormalities in the spinal upper motor neurons, and no detrusor response to cold temperature occurs in patients with abnormalities in lower motor neurons or in patients with no neurological abnormalities.³⁵ On the basis of these results, use of room-temperature saline probably would not alter interpretation of our results.

Our findings support the WSACS recommendation for instilling 25 mL of normal saline into the bladder before measuring IBP because compared with no instillation, this amount reduces variability and improves reliability. We did not investigate the reliability of IBP measurements with volumes larger or smaller than 25 mL, and we cannot comment on whether higher reliability could be obtained with a higher or lower volume. For instance, Kimball et al¹² found higher interobserver and intraobserver rater reliability of IBP measurements when 50 mL of physiological saline was used.

Recommendations for Patients' Position

AACN⁴ and WSACS¹ recommend that IBP be measured with patients in the supine position only, but a rationale for this recommendation has not been provided. Studies^{21,36,37} have shown that IBP measured with patients in the supine position with no elevation of the head of the bed is lower than IBP measured with patients supine and any degree of elevation. This finding is to be expected, because any elevation of the head of the bed increases abdominal wall tension and increases the gravitational effect of intra-abdominal organs on IBP.²⁷ However, positioning patients supine even for a short period just for the purpose of measuring IBP increases the risk of aspiration pneumonia and is against recent practice guidelines³⁸ that recommend ICU patients have the head of the bed elevated a minimum of 30° at all times. Our results indicate that experienced ICU nurses can obtain highly reproducible IBP measurements by following a standardized protocol with patients supine and the head of the bed elevated 30°. This finding is important for clinical practice because most patients are positioned supine with the head of the bed elevated 30° most of the time in the ICU, and IBP is

Instillation of 25 mL of physiological saline reduced the measurement variability and increased reliability.

measured more than once per day and by more than one nurse in a day. Maintaining patients supine with the head of the bed elevated 30° should reduce the risk of equipment dislodgement and decrease the risk of aspiration pneumonia for patients receiving mechanical ventilation and enteral nutrition.³⁸ Furthermore, measuring IBP with patients in this position is convenient for them, especially those who have difficulties achieving the supine position, and also reduces ICU nurses' workload. Because of these practical advantages, the supine position with the head of the bed elevated 30° should be considered as the recommended position for measuring IBPs.

Limitations

Our study has several limitations. First, only intraobserver and interobserver reliabilities of IBP measurements in patients who were positioned supine with the head of the bed elevated 30° were assessed, and IBP was only measured with instillation of 0 and 25 mL of normal saline. Studying other positions and smaller and larger instillation volumes would have strengthened the study. Second, only 2 experienced ICU nurses collected data, and we do not know if similar results would be obtained by less experienced or novice nurses. Third, we did not address other potential sources of variability such as the ability of the ICU nurse to correctly identify the anatomic location of the reference point used to level and zero the transducer²² or the ability of the ICU nurse to interpret the pressure wave from the monitor.³⁹

Last, we measured IBP in a small and relatively homogeneous number of patients. Despite efforts to recruit more critically ill patients into the study, most of the patients (93%) who participated were not sedated or receiving mechanical ventilation. Patients who were sedated or receiving mechanical ventilation could not give informed consent, and their surrogate decision makers did not give informed consent to participate in this study. For this study, 260 patients were approached, and only 120 gave informed consent. In addition, in some instances, the attending physician and/or the bedside nurse did not refer a patient because of an unstable clinical status or other reasons. Other critical care studies have this same limitation.⁴⁰

Clinical Implications and Future Research

Measurement of IAP is the new frontier in critical care monitoring. Before this technique becomes more widely used and becomes a standard of care to guide the medical management of patients, nurses should critically assess each aspect of IAP measurement and

application. Failure to do so will risk committing the same mistakes that have occurred with hemodynamic measurements.^{41,42}

Because abdominal compartment syndrome is defined on the basis of measurements of IBP obtained with patients supine, and if the supine position with the head of the bed elevated 30° is to be used instead, further studies are needed in more heterogeneous ICU populations to identify the levels of IBP in patients supine with the head of the bed elevated 30° that indicate abdominal compartment syndrome and need for treatment. In addition, further studies are needed to delineate additional key elements of IBP measurement, such as the proper anatomic reference for the positioning and leveling of the transducer, the temperature of the physiological saline instilled, and the contribution of bedside nurses' knowledge and experience related to IBP measurement.

Addendum

This research was a subordinate reliability study conducted within a larger prospective randomized observational study whose aims were to systematically explore the effects of patient position and volume of saline instilled on measurement of IBP and to identify other clinical factors that influence IBP measurements. Although the larger study is not germane to this article, understanding the design of the larger study is helpful. Briefly, 120 patients who consented to participate were randomized to 1 of 12 groups (10 patients per group). The 12 groups were combinations of 4 body positions and 3 instillation volumes. The 4 positions were supine with no elevation of the head of the bed (flat), supine with the head of the bed elevated 30°, right lateral with the head of the bed elevated 30°, and left lateral the head of the bed elevated 30°. The volumes of saline instilled were 25, 50, and 200 mL. The randomization scheme was prepared by the statistician and delivered to the principal investigator in sealed envelopes that were opened after the patients signed the informed consent forms. The complete description, design, and results of the parent study can be found elsewhere.²¹

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CE Test Test ID A1019042: Reliability of Intrabla dder Pressure Measurement in Intensive Care.

Learning objectives: 1. Describe the importance of establishing reliability of intrabla dder pressure (IBP) measurements in critically ill patients. 2. Identify the factors that affect IBP measurements. 3. Discuss the nursing implications associated with obtaining accurate intra-abdominal pressure (IAP) and IBP measurements in critical care patients.

- Which of the following variables in this study represents the recommendation of the World Society of Abdominal Compartment Syndrome?**
 - Instillation of 0 mL of physiological saline
 - Instillation of 25 mL of physiological saline
 - Measurement of IBP with the patient supine and flat
 - Measurement of IBP with the patient supine and the head of the bed elevated 30°
- The physiological saline used as instillation fluid in this study was kept at which of the following temperatures?**
 - 37° C
 - 35° C
 - 30° C
 - 22° C
- Why was the AbViser device not removed between the first set of measurements and the second and third set of measurements?**
 - To reduce the risk of infection
 - For nurses' convenience
 - To promote patient comfort
 - To decrease the potential for variability of measurements between different nurses
- When using Bland-Altman as a form of data analysis, the difference between 1 measurement and the mean of the measurements is called what?**
 - Variability
 - Bias
 - Mean
 - Standard deviation
- Which of the following relationships existed between the IBPs measured after instillation of 0 mL and 25 mL of saline?**
 - The IBP measured after instillation of 25 mL of saline resulted in greater variability as compared to IBP measured after instillation of 0 mL.
 - The IBP measured after instillation of 25 mL of saline resulted in lesser variability as compared to IBP measured after instillation of 0 mL.
 - The IBP measured after instillation of 0 mL of saline resulted in similar variability as compared to IBP measured after instillation of 25 mL.
 - The IBP measured after instillation of 0 mL of saline resulted in greater variability as compared to IBP measured after instillation of 25 mL.
- Which of the following patient characteristics may help explain the low variability of the findings in this study?**
 - All of the patients in the study were extremely ill.
 - All of the patients in the study were receiving continuous intravenous fluids.
 - No patients included in the study were sedated.
 - No patients included in the study stayed more than 3 days in the intensive care unit.
- Increased abdominal wall tension is an expected result of which of the following?**
 - Elevation of the head of the bed
 - Instillation of body temperature (37° C) normal saline into the bladder
 - Clamping of the urinary drainage collection tubing
 - Instillation of room temperature (22° C) normal saline into the bladder
- Measuring of IBP without instillation of saline should be avoided because it results in which of the following?**
 - Inability to detect a fluid wave
 - Increased bladder compliance
 - Greater variability in IBP measurements
 - Increased risk of infections
- Why is IAP estimated indirectly in critical care by measuring IBP?**
 - Indirect measurement using IBP alleviates much of the variability that occurs from differences in technique between care providers.
 - Direct measurement of IAP is very costly.
 - Indirect measurement allows for continued monitoring of estimated IAP between IBP measurements.
 - Direct measurement of IAP is difficult.
- Highest reliability and lowest variability of IBP measurements as estimated by the Bland-Altman method would be indicated by which of the following?**
 - Bias of 10 mm Hg
 - Bias of 0.6 mm Hg
 - Bias of -1.8 mm Hg
 - Bias of -4 mm Hg
- Which of the following best describes the method for measuring IBPs used in this study?**
 - Measurements were obtained twice by one nurse and twice by a second nurse.
 - Measurements were obtained once by one nurse and once by a second nurse.
 - Measurements were obtained once by one nurse and once by a second nurse.
 - Measurements were obtained twice one nurse and once by a second nurse.
- According to the protocol for measurement of bladder pressures used in this study, when were intrabla dder pressures to be recorded?**
 - At the end of inspiration
 - At the end of expiration
 - At the start of inspiration
 - At the start of expiration

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