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Comparing intra-abdominal pressures in different body positions via a urinary catheter and nasogastric tube: a pilot study

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Abstract

Objectives: Intra-abdominal pressure (IAP) is most commonly measured via the bladder with the patient in the supine position. In the ICU, patients are nursed with the head of the bed elevated at 30° (HOB30) to reduce the risk of ventilator-associated pneumonia. This study investigated whether gastric pressure at HOB30 can be used as a surrogate measure of IAP via the bladder in the supine position.

Methods: A prospective observational study was conducted in a single-centre intensive care unit. A total of 20 patients were included. IAP was recorded simultaneously via the bladder catheter (bladder pressure, IBP) and via nasogastric tube (gastric pressures, IGP) in the supine and HOB30 position. Each patient had three sets of IAP measurements performed at least 4 h apart.

Results: In the supine position, mean IBP was 12.3 ± 4.5 mmHg compared to IGP of 11.8 ± 4.7 mmHg. The bias between the two groups was 0.5 and precision of 3.7 (LA, -6.8 to 7.5 mmHg). At 30 degrees, mean IBP was 15.8 ± 4.9 mmHg compared to IGP of 13.1 ± 6.1 mmHg. The bias between both groups was 2.7 with a precision of 5.5 (LA, -8.0 to 13.5). Comparing IBP in the supine position with IGP at 30° showed a bias of -0.8 and precision of 5.6 (LA, -10.1 to 11.6 mmHg).

Conclusion: IAP measured via a nasogastric tube was less influenced by changing the body position from supine to HOB30 than was bladder pressure.

Introduction

Intra-abdominal hypertension (IAH) and abdominal compartment syndrome (ACS) are associated with increased morbidity and mortality in critically ill patients [1,2]. As a result, evidence-based consensus definitions and recommendations for resuscitation and management of IAH and ACS have been developed [3,4]. The general approach is based on four principles: (a) serial IAP monitoring, (b) medical management to reduce IAP, (c) goal-directed optimisation of systemic perfusion and organ function and (d) early surgical decompression for IAH/ACS refractory to these interventions. Cheatham and Safcsak showed that implementing these recommendations including serial IAP monitoring and early abdominal decompression at an IAP of 25 mmHg

significantly increased patient survival to hospital discharge from 50% to 72% [5].

The World Society of Abdominal Compartment Syndrome (WSACS; <http://www.wsacs.org>) recommends the measurement of IAP via the bladder in the supine position at end-expiration, ensuring that abdominal contractions are absent and with the transducer zeroed at the level of the mid-axillary line [3,4]. Intermittent and continuous measurement of IAP via the stomach, bladder and peritoneal cavity have been validated and used when this method is contra-indicated [6].

In the intensive care unit, most ventilated patients are nursed with the head of the bed elevated at 30° or 45° to reduce the risk of ventilator-associated pneumonia and gastric reflux [7,8]. Measuring IAP in the semi-recumbent position has been shown to adversely affect IAP readings when measured via the intravesical route [9,10]. The aim of our study was to compare the influence of body position, specifically head of bed elevation at 30°

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(HOB30), on bladder and gastric pressure. Furthermore, we examined the correlation between the intrabladder pressures (IBP) and intragastric pressures (IGP) in the supine and HOB30 position. Our hypothesis was that IGP at 30° are not influenced by the descent of abdominal contents in the semi-recumbent position and therefore would represent IBP in the supine position.

Materials and methods

The Human Research Ethics Committee of Fremantle Hospital approved this prospective pilot study.

Patient selection

Patients who were admitted to the Intensive Care Unit at Fremantle Hospital between December 2009 and April 2010 were consecutively enrolled in the trial. Patient inclusion criteria required them to be older than 18 years of age, to be sedated and mechanically ventilated and to have both a nasogastric tube and indwelling urine catheter in place. Reasons for exclusion were recent oesophageal, gastric or bladder surgery; patients who were moribund and unlikely to survive 24 h; patients who were pregnant and patients who were unable to lay flat for any reason. Patients were sedated to a Richmond Agitation and Sedation Scale of -5 (RASS) to ensure that abdominal muscle contractions were absent. Written informed consent was obtained by the next of kin as determined by the ethics committee.

Bladder pressure

Once the patient was enrolled, IBP was measured according to the WSACS consensus recommendations using the standard bladder technique [3]. The IBP was measured through the patient's indwelling catheter, according to the modified Kron technique using an AbViser 300 or AbViser 611 kit (AbViser, Wolfe Tory Medical, Salt Lake City, UT, USA) [11,12]. The transducer was zeroed on the mid-axillary line at the level of the superior iliac crest. After 20 ml of normal saline was injected through the indwelling urine catheter, the IAP was measured at end-expiration in millimetres of mercury. The pressure transducer was connected to the electronic monitoring equipment available in the intensive care unit.

Gastric pressure

Gastric pressures were measured via a standard nasogastric tube. Prior to measurement, the nasogastric tube was aspirated for air or gastric contents, and its position was confirmed by chest X-ray. A three-way stopcock was attached between the nasogastric tube and a standard pressure monitoring line. A Luerlok syringe was attached to one port of the stopcock for the instillation of 100 ml of sterile saline from the closed pressure monitoring system to ensure a continuous column of fluid between the

stomach and the pressure transducer. A point level with the xiphisternum on the mid-axillary line was marked, and the transducer was zeroed at that level. This position corresponds to the position of the stomach allowing accurate measurement of gastric pressure in different body positions. After each measurement, the instilled volume of saline was then aspirated out of the nasogastric tube.

Protocol

Each set of measurements included IBP and IGP in the supine position followed by the semi-recumbent position at HOB30. All four measurements were taken over a period of 5 to 10 min or less to reduce the possibility of changes in IAP over time. Three sets of readings were taken at least 4 h apart over a 24-h period.

Data collection

Once patients were enrolled in the study, data on patient demographics including age, sex, weight, height, body mass index, diagnosis at admission, co-morbidities and presence of IAH risk factors were collected. Severity of illness for the 24-h period before the first IAP measurement was documented through calculation of the Acute Physiology and Chronic Health Evaluation score II, Simplified Acute Physiology Score II and Sequential Organ Failure Assessment Scores. For each set of IAP readings, mean arterial pressure, positive end-expiratory pressure and RASS were recorded. All study data were recorded on a case report form on paper and subsequently entered as de-identified patient data on a secure Microsoft Access database.

IAH was defined by a sustained or repeated pathological elevation in IAP ≥ 12 mmHg, whilst ACS was defined as a sustained IAP > 20 mmHg that is associated with new organ dysfunction/failure [3].

Statistical analysis

Statistical analysis was performed using Medcalc (Medcalc version 9.3.5.0, Mariakerke, Belgium) and PASW Statistics 18 (SPSS Inc., Chicago, IL, USA). Data are presented as proportions (with 95% confidence interval as appropriate) or mean \pm standard deviation (SD). Paired Student's *t* tests were used to test for statistical significance between two different measures of pressure on the same patients at the same times. General linear modelling (GLM) for repeated measures was used to test whether differences between the same measures of pressure on the same patients changed significantly over time. A significant level of $p < 0.05$ was used throughout. For assessing agreement between two methods of measurement of IAP, we used Bland-Altman plots [13]. The WSACS recommends a bias below 1 mmHg and a precision (defined as the standard deviation of the bias) of 2 mmHg, or thus, limits of agreement

of -4 to +4 mmHg are necessary for two IAP techniques to be considered equivalent [14]. Pearson correlation plots were also utilised to assess agreement between the two methods. The Pearson correlation (r^2) is +1 in the case of a perfect positive (increasing) linear relationship, and as it approaches zero, there is less correlation.

Results

There were 20 patients enrolled in the study with a total of 240 IAP measurements. Patient demographics and severity of illness are presented in Table 1. One patient presented with an ACS, and of the remaining 19 patients, nine presented with IAH (47.4%). Sixty-five percent of the patients were medical, 30% were surgical and one patient (5%) was enrolled after trauma.

GLM for repeated measures showed that for all four measures, the IAP did not change significantly over time (Huyn-Feldt test for within-subjects effects $p > 0.34$; Bonferroni-corrected pairwise comparisons, $p \geq 0.50$). Therefore, the results for all 60 sets of measurements were pooled.

In the supine position, the mean IBP was 12.3 ± 4.5 mmHg compared to an IGP of 11.8 ± 4.7 mmHg (Figure 1). In HOB30 position, the mean IBP was $15.8 \pm$

4.9 mmHg compared to the mean IGP of 13.1 ± 6.1 mmHg (Figure 2). The mean difference in the supine position for IGP and IBP was -1.3 ± 4.6 mmHg ($p = 0.037$), whereas the mean difference in the HOB30 for IGP and IBP was -3.5 ± 3.0 mmHg ($p < 0.001$) (Figure 3). Bias, precision, limits of agreement and coefficient of determination comparing different pressure measurements are shown in Table 2.

Discussion

This study found that IGP changed to a lesser degree than IBP when changing the body position from supine to HOB30. The WSACS recommends using the IBP in the supine position to indirectly measure IAP, but gastric pressures have shown to be a valid alternative in cases where the bladder is contra-indicated. Collee et al. [15] used a simple water column technique to measure IGP in 26 intensive care patients and found a good correlation between bladder and gastric pressures. Sugrue et al. [16] showed with a modified nasogastric tube (air-filled) that in nine patients undergoing laparoscopic cholecystectomy, the IGP reflected IBP accurately (mean difference of 0.35 mmHg). Turnbull et al. [17] also used air-filled balloon catheters and compared them with direct IAP measurement. They found an estimated 2.5-mmHg difference between both techniques which is acceptable. Semi-continuous measurement of IAP using an intra-gastric compliance catheter has shown a good correlation between gastric and direct IAP measurement with a mean difference of only 0.12 mmHg and acceptable limits of agreement [18]. Similar results were published in vitro [19] and in vivo [20,21]. However, this could not be confirmed by Davis et al. [22] who demonstrated in children that the bias between nasogastric and bladder pressures was 1.3 mmHg with limits of agreement of -5.42 and 2.82. Becker et al. showed that continuous IAP measurements via the CiMON catheter (Pulsion Medical Systems, Munich, Germany) in cirrhotic patients did not correlate well with direct IAP measurements (bias of 4.9 mmHg) [23]. Finally, some animal studies have shown poor correlation between IGP and IBP [10].

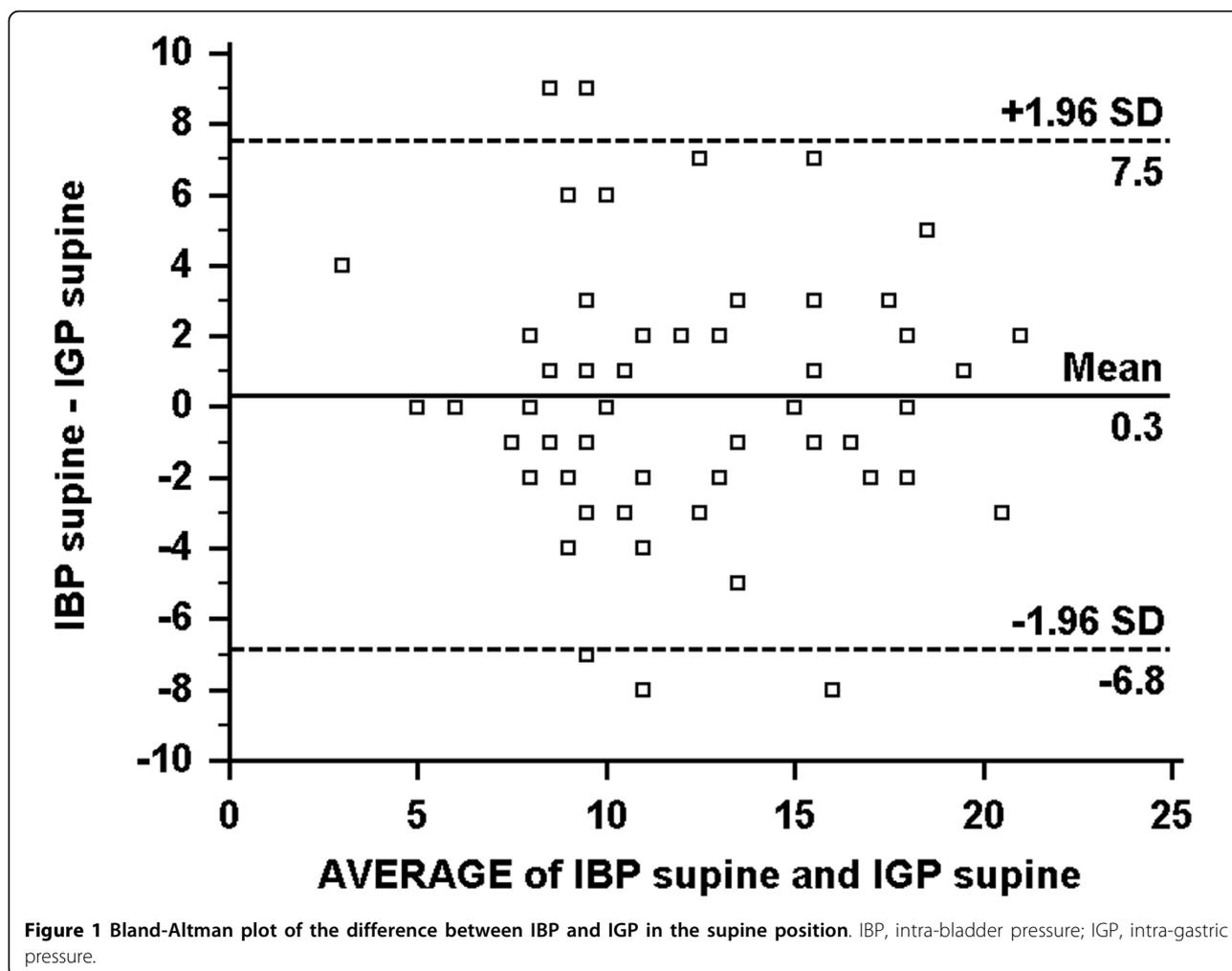
Most patients in the ICU are nursed with the head of bed elevated at 30° to 45° to reduce the risk of ventilator-associated pneumonia [7,8]. Studies have shown that placing these patients in the semi-recumbent position significantly increases IAP [10]. This could lead to an over-estimation of the measured IAP.

Ideally, we need to have a method of measuring IAP in HOB30. In this study, IGP HOB30 was compared with the gold standard IAP supine via the bladder. Comparing the two methods, we found an acceptable bias, but the precision and limits of agreement exceeded the pre-defined range [14]. Therefore, based on our results, we

Table 1 Patient demographics

Patients (n)	20
Age (years)	57 ± 19
Weight (kg)	88 ± 22
Height (cm)	171 ± 10
BMI (kg/m ²)	30 ± 7
Male/female ratio	12/8
Severity of illness scores	
APACHE II	15 ± 7
SAPS II	35 ± 13
SOFA	8 ± 3
Etiology of illness (%) (n)	
Surgical	30% (6)
Medical	65% (13)
Trauma	5% (1)
Co-morbidities (%) (n)	
COPD	25% (5)
Chronic renal failure	10% (2)
Diabetes	40% (8)
Liver diseases	5% (1)
Malignancy	5% (1)
Hypertension	30% (6)
Heart disease	10% (2)
Hyperlipidemia	15% (3)

Data expressed as means \pm SD or % (n). APACHE II, Acute Physiology and Chronic Health Evaluation, version II; SAPS II, Simplified Acute Physiology Score, version 2; SOFA, Sequential Organ Failure Assessment Score; COPD, chronic obstructive airway disease; BMI, body mass index.



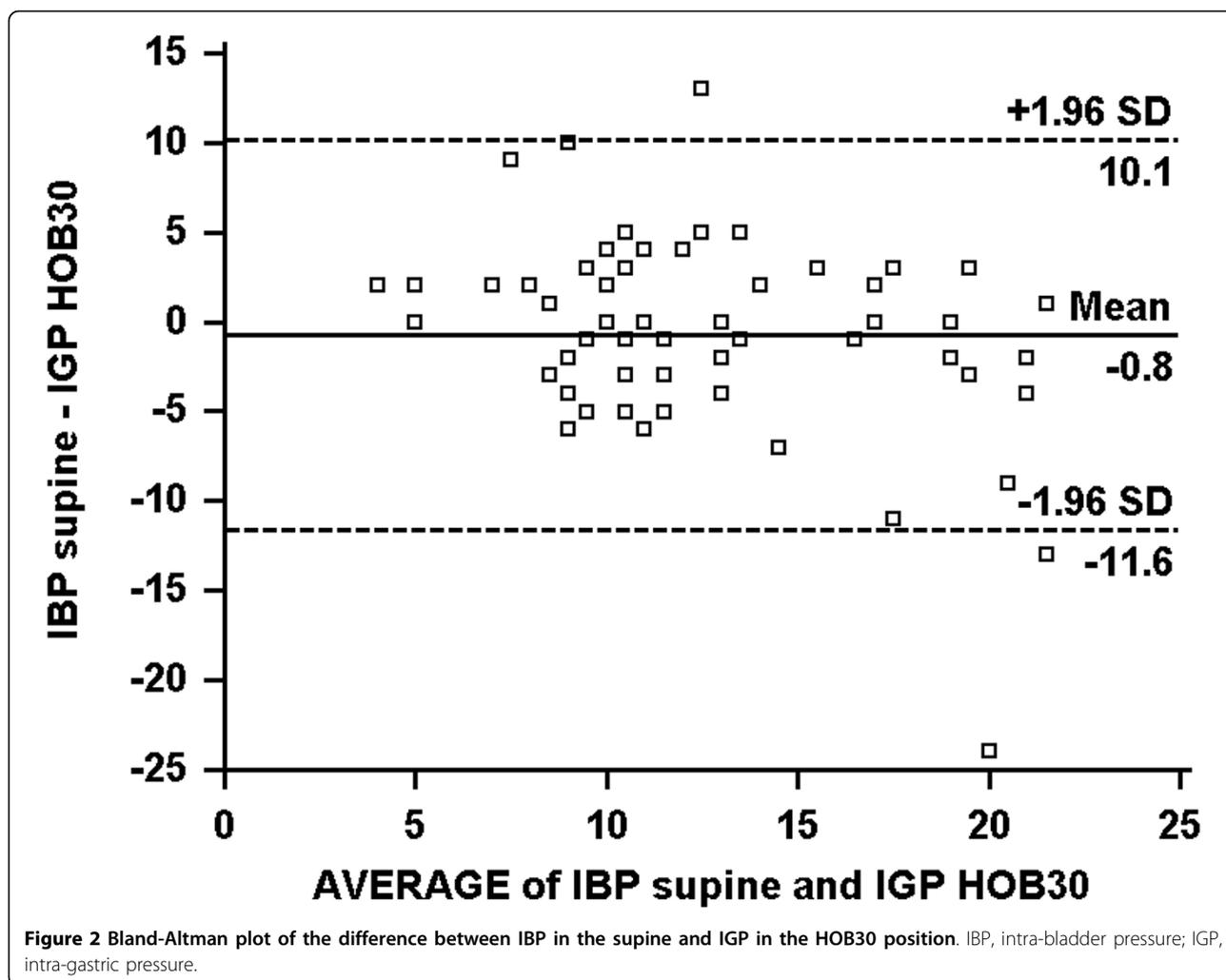
currently cannot recommend the use of IGP in the HOB30 to be used as an alternative to IBP in the supine position.

It is uncertain if this IBP increase between supine and HOB30 is a true pressure increase throughout the entire abdomen or represents a pressure gradient within the abdomen caused by a hydrostatic fluid column or a compression of abdominal organs with a subsequent compression on the bladder or even a localized pressure difference [10].

There might have been extra-abdominal body components such as the mediastinum or lungs increasing IAP, which might have affected IGP and IBP readings to different extent. If we believe that the abdomen behaves as a hydraulic system [10], then the IBP increase between supine and HOB30 is real and clinicians should take this into account in patients with impending ACS. Further research needs to be directed towards whether the abdomen is a truly fluid container or whether it is made up of different organs with fluid and air-filled

contents exerting varying pressures on these compartments as this may help explain the significance of higher semi-recumbent measurements [24].

The main limitations of our trial are that it only represented a very small group of patients. Forty percent of the patients had IAH but only one patient had ACS, and we cannot be certain that with higher IAP values the correlation between IBP in the supine position and IGP in the HOB30 might have improved. Although we did pay attention to make sure that the stomach was in a period of quiescent motor activity with no evidence of the phase 2 or 3 of the migrating motor complex, this could not be excluded entirely and may have influenced the IGP readings. Gastric motor activity was recorded by Collard and Romagnoli at a rate of about three cycles per minute [25]. Enteral feeding and ileus may also have compromised the accuracy of the IGP. However, as the IGP was lower than the IBP in the supine position, we do not think the gastric activity had a great influence on the gastric pressure. Furthermore, any residual air or



residual gastric contents left in the tubing (something that is difficult to assess) might give erroneous pressure readings, hence influencing IGP. The zero reference position for measuring IGP on the mid-axillary line at the level of the xiphisternum might have influenced the readings at HOB30 when comparing with the supine position. Finally, the optimum amount of fluid to be instilled into the stomach is still unknown.

As for IBP measurements, increasing volume of fluid installed into the bladder can produce falsely elevated measurements. Therefore, the amount of 100 ml of normal saline might have been too high to adequately measure IGP. Some of these questions may be solved through bypassing the effects associated with fluid-filled systems and measuring IAP with a balloon-tipped catheter.

There are no guidelines towards critical IAP levels in patients with the HOB elevated, and it may well be that the higher readings ascertained in this position are accurate. Further research should be directed as to whether

early interventions for raised IAP in the semi-recumbent position provide better outcomes in patients with ACS. Based on our results, IGP in the semi-recumbent position cannot be recommended as an estimate for IAP in supine position. Instead, IAP should be taken via an indwelling bladder catheter with the patient in a supine position to standardize values when intermittent readings are required. If readings are taken in different positions or by different routes, accuracy is reduced.

Conclusions

Based on our results, IGP at HOB30 position cannot be used as a surrogate measure of IBP in supine position. Although previous studies have implicated that IGP and IBP can be used interchangeably, we found large limits of agreement between the two methods. IAP measured via the nasogastric tube was less influenced by position than was the IAP measured via bladder catheter. Further research is required to assess the implication of increased IAP readings in the semi-recumbent position

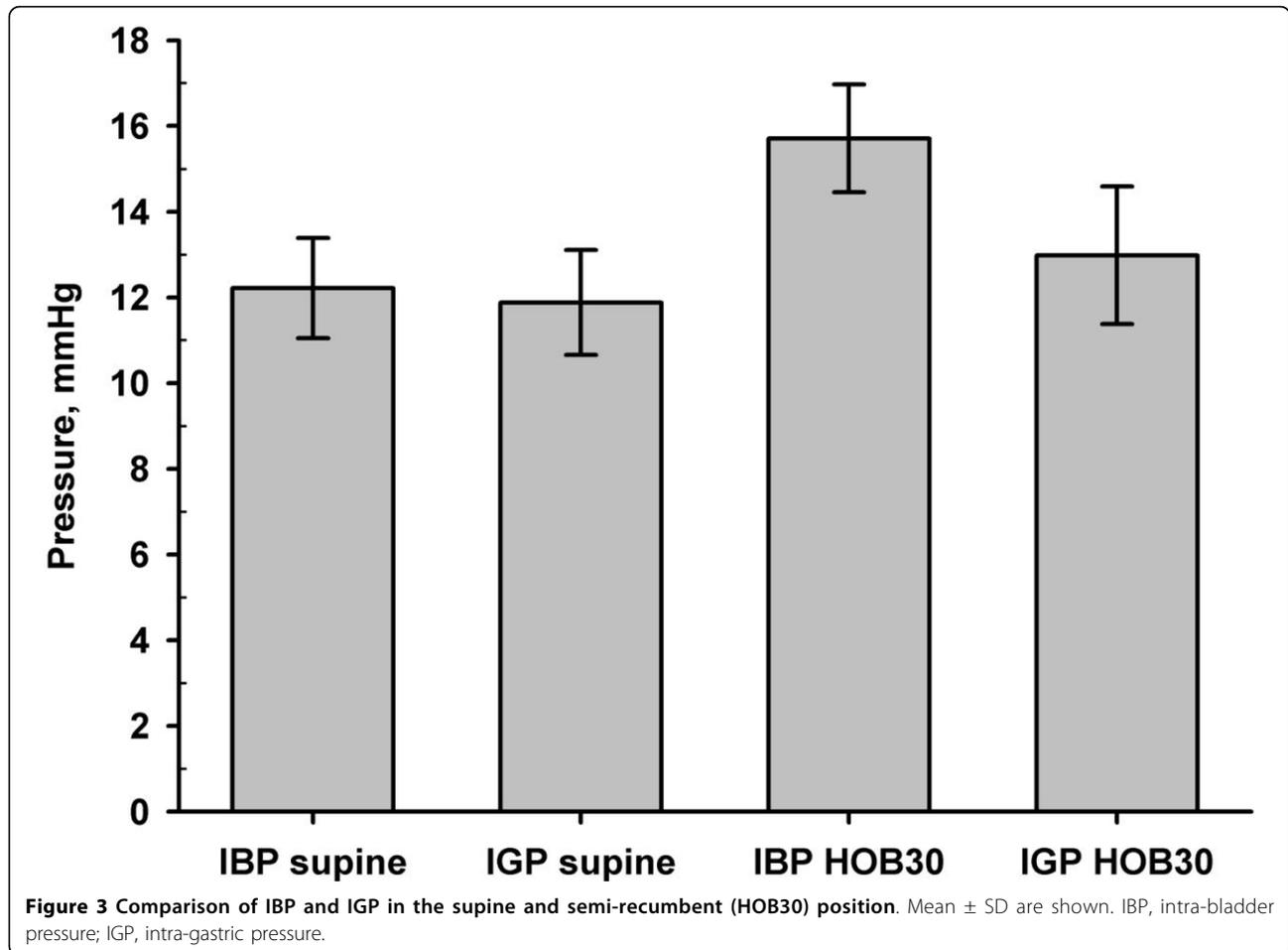


Table 2 Comparison between different pressure sites and body positions

	Bias (95% CI) in mmHg	Precision (limits of agreement) in mmHg	R ²	SE
IBP supine vs IGP supine	0.3 (-0.6 to 1.3)	3.7 (-6.8 to 7.5)	0.42	27.4
IBP HOB30 vs IGP HOB30	2.7 (1.3 to 4.1)	5.5 (-8.0 to 13.5)	0.28	11.2
IBP supine vs IGP HOB30	-0.8 (-2.2 to 0.7)	5.6 (-10.1 to 11.6)	0.25	39.2

Bias, precision, limits of agreement and coefficient of variation (R²) comparing different pressure measurements. IBP, intra-bladder pressure; IGP, intra-gastric pressure; HOB30, head of bed elevated at 30°; 95% CI, confidence interval; SE, standard error (2 × SD/mean IAP)

and whether this is due to the abdomen not being a hydraulic compartment or whether this reflects a true local increase in IAP.

Abbreviations

ACS: abdominal compartment syndrome; GLM: general linear modelling; HOB: head of bed elevation; HOB30: head of bed elevation at 30°; IAH: intra-abdominal hypertension; IAP: intra-abdominal pressure; IBP: intrabladder pressures; IGP: intragastric pressures; LA: limits of agreement; RASS: Richmond Agitation and Sedation Scale; SD: standard deviation; WSACS: World Society of Abdominal Compartment Syndrome.

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To standardize IAP measurement technique, Wolfe-Tory provided the AbViser bladder pressure measurement kits free of charge.

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Authors' contributions

NR, BDK and AR participated in the design of the study. BDK and NR contributed to data collection. BDK, AR and WD performed the statistical analysis. NR and BDK drafted the manuscript. AR, NR and WD revised the manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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