Is it feasible to measure intra-abdominal pressure using a balloon-tipped rectal catheter? – Results of a pilot study

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Abstract

Background

The gold standard to measure intra-abdominal pressure (IAP) is via intra-vesical measurement via the urinary bladder. However, this technique is restricted in ambulatory settings because of the risk of iatrogenic urinary tract infections. Rectal IAP measurements (IAP_{rect}) may overcome these limitations, but requires validation. This pilot study aims to validate the IAP_{rect} technique against standard intra-vesical IAP measurements (IAP_{ves}).

Methods

IAP_{rect} using an air-filled balloon catheter and IAP_{ves} using Foley Manometer Low Volume were measured simultaneously in sedated and ventilated patients. Measurements were performed twice in different positions (supine and 45° elevated head of bed) and with an external abdominal velcro belt.

Results

Sixteen patients were included. Seven were not eligible for analysis due to unreliable IAP_{rect} values. IAP_{rect} was significantly higher than IAP_{ves} for all positions ($p<0.001$) and the correlation between IAP_{ves} and IAP_{rect} was not significant in any position ($p\geq0.25$, bias 7.2mmHg, LOA -3.5 to 18mmHg). Repeatability of IAP_{rect} was not reliable ($r=0.539$, $p=0.315$). For both techniques, measurements with the external abdominal velcro belt were significantly higher compared to those without ($p<0.030$).

Conclusions

IAP_{rect} has important shortcomings making IAP estimation using a rectal catheter unfeasible because the numbers cannot be trusted nor validated.

Introduction

Intra-abdominal pressure (IAP) is the steady state pressure inside the abdominal cavity and is normally less than 7 mmHg in healthy adults with higher physiological baseline levels (9 to 14 mmHg) in morbidly obese patients (1, 2). Critically ill patients usually have baseline IAP of approximately 10 mmHg (3). Intra-abdominal hypertension (IAH) is defined by the World Society of the Abdominal Compartment (WSACS), formerly known as the World Society of the Abdominal Compartment Syndrome (www.wsacs.org), (4, 5) as a sustained increased in IAP ≥ 12 mmHg, and abdominal compartment syndrome as IAP > 20 mmHg with new onset organ failure (6–8). A pathologically increased IAP is often seen in critically ill patients and this may have detrimental consequences such as acute renal failure, hemodynamic instability, inadequate ventilation and decreased blood flow to organs (9, 10). It has been suggested that gestational complications such as preeclampsia might also be associated with intra-abdominal hypertension (11–13), making IAP an important consideration in obstetric (patho) physiology as well.

Urinary bladder pressure measurement, by using a FoleyManometer Low Volume (FMLV), is recognised as the gold standard to measure IAP (14). This technique is easily applicable in catheterized patients, but its use is restricted in ambulatory settings because of risks of iatrogenic urinary tract infections. The abdomen behaves according to Pascal's Law, thus rectal pressure measurements proximal of the pelvic floor muscles should also represent IAP similar to intravesical pressure. Rectal pressures are used routinely as estimates for IAP during urodynamic studies to calculate transmural detrusor muscle pressure (intravesical pressure minus IAP measured rectally) (15–17). Measurement using a rectal catheter is less invasive and can be used in ambulatory settings and in pregnant patients, however, validation of this technique is required. This pilot study aims to validate the rectal intra-abdominal pressure (IAP_{rect}) technique against standard intra-vesical IAP measurements (IAP_{ves}).

Material And Methods

The study was conducted at the Ziekenhuis Netwerk Antwerpen (ZNA Campus Stuivenberg, Antwerp, Belgium) in accordance with the study protocol, the Declaration of Helsinki and applicable regulatory requirements. The study was approved by the local Institutional Review Board and Ethics Committee of ZNA (Antwerp, Belgium) (IC Approval 3001) and Ziekenhuis Oost-Limburg (Genk, Belgium) (EC 12/084U). Oral and written informed consent was obtained from the relatives of all patients and there were no deviations from standard clinical practice.

Patient selection

Sedated and ventilated patients admitted to the ICU (Ziekenhuis Netwerk Antwerpen, ZNA Campus Stuivenberg, Antwerp, Belgium) were included from December 2014 to May 2015. Exclusion criteria were patients younger than 18 years and those in whom there was a medical contraindication for rectal or urinary bladder catheterisation. Demographic data were recorded for all patients.

Pressure measurements

In most patients, a urinary catheter was already in place with a Foley Manometer Low Volume (FMLV, Holtech, Medical, Charlottenlund, Denmark) attached. If not, a urinary catheter was inserted prior to FMLV attachment. In case of an empty urinary bladder or the presence of air-bubbles obstructing a continuous fluid column in the FMLV, 20 ml of 0.9% sterile sodium chloride solution was injected via the FMLV urine sample port using an aseptic technique. Baseline IAP was measured in the supine position using the FMLV (IAP_{ves}) with the zero-reference point in the midaxillary line at the level of the iliac crest (as recommended by WSACS) (14, 18). IAP was noted at end-expiration, when the meniscus of the fluid column had stabilized and oscillated with the breathing efforts.

The IAP_{rect} was measured using a rectal T-DOC 7Fr air-filled balloon catheter (Laborie Medical Technologies, Mississauga, Canada) connected to a computer displaying the IAP (Audact Pro database version 7.11, Ellipse Andromeda, Urotex.). The balloon was inflated with air using a switch, zeroed at atmospheric pressure and inserted 15 cm into the rectum after digital rectal palpation to remove impacted faeces. The catheter was attached to the patient's leg to prevent displacement.

Protocol

IAP is most accurate when measured in a supine position (8, 16). To validate the accuracy of IAP_{rect} with increasing IAP, measurements were performed in 2 positions in an attempt to artificially increase IAP; the 45° elevated head of bed semirecumbent position, followed with an external abdominal velcro belt (similar to that used by surgeons to prevent incisional hernias). The abdominal belt was put on manually and fastened with a velcro tape and was not released during the protocol. IAP_{ves} and IAP_{rect} were measured simultaneously according to a standardized protocol (Fig. 1). All positions (except the application of the external abdominal pressure belt) were repeated twice, including the insertion of the rectal catheter.

Statistical analysis

All statistics were performed using SPSS 22.0 software (SPSS inc., Chicago, USA), at nominal level $\alpha = 0.05$. Correlations between IAP_{ves} and IAP_{rect} were evaluated using univariate linear regression analysis and Pearson correlation. Bland-Altman plots were performed using MedCalc (MedCalc BVBA, Software version 13.0.2, Ostend, Belgium). Values were compared using a paired or independent sample *t*-test as appropriate.

Results

Sixteen patients were included, of whom 7 (43.8%) were not eligible for analysis as all IAP_{rect} measurements were unreliable due to IAP_{rect} values out of physiological range (> 40 mmHg) or strongly fluctuating (> 50%). These patients were found to have profound diarrhoea (n = 1), faecal impaction (n = 2), abdominal muscle contractions in a subconscious patient (n = 1) and difficult placement of the catheter due to anal skin tags and haemorrhoids (n = 1) or morbid obesity (n = 2). An example of both invalid and valid measurement is shown in Fig. 2. The men/women ratio of the of the 9 remaining patients (56.2%) eligible for further analysis was 7/2, mean age 59.0 ± 13.5 years and mean BMI 26.9 ± 6.8 kg/m². Patients were admitted to ICU for sepsis (n = 3), vascular disease, liver cirrhosis, exacerbation of COPD, pneumonia, and major trauma (n = 2).

Four patients had only one set of measurements and the external abdominal pressure belt was contra-indicated in one patient because of rib fractures, therefore there were in total 14 paired measurements without and 8 measurements with the abdominal belt. Table 1 shows the mean IAP_{ves} and IAP_{rect} in both positions, with or without the external abdominal pressure belt. IAP_{ves} was lowest in the supine position (13.6 ± 3.1 mmHg), however, not significantly different from measurement obtained in the semi-recumbent position (15.7 ± 4.4 mmHg, p = 0.103). Measurements with the abdominal pressure belt were significantly higher compared to those without ($p < 0.030$). Figure 3 shows a boxplot of the median IAP_{ves} and IAP_{rect} values in the different body positions.

Table 1
Correlation between intravesicular and intrarectal pressure in different positions with and without an external abdominal pressure belt.

	Supine (n = 14)	45° (n = 14)	$Supine_{APB}$ (n = 8)	$45°_{APB}$ (n = 8)
IAP_{ves}	13.6 ± 3.1	15.7 ± 4.4	17.9 ± 3.4	20.9 ± 4.6
IAP_{rect}	20.8 ± 5.0	24.4 ± 4.8	26.1 ± 5.1	29.2 ± 6.8
PCC	0.159	0.344	0.283	0.152
p-value	0.588	0.25	0.497	0.745
r^2	0.153	0.277	0.370	0.142

Data are presented as mean ± standard deviation. Correlations reported between IAP_{ves} and IAP_{rect}.

PCC: Pearson correlation coefficient; IAP_{ves}: Intravesical pressure; IAP_{rect}: intrarectal pressure; 45°: 45° head-of-bed (HOB) semirecumbent position; APB: abdominal pressure belt

IAP_{rect} in the supine position was significantly lower compared to measurements in the semi-recumbent position (20.8 ± 5.0 mmHg versus 24.4 ± 4.8 mmHg, $p = 0.002$ for supine and semirecumbent, respectively) and measurements with the abdominal pressure belt were significantly higher than without, ($p = 0.032$ and $p = 0.003$ for IAP_{rect} in supine and semi-recumbent positions, respectively).

IAP_{rect} was significantly higher than IAP_{ves} for all positions ($p < 0.001$) and reached the threshold of IAH (≥ 12mmHg) in all patients, against 64.3% for the IAP_{ves} measurements. The IAP difference when moving from supine to 45° HOB semi-recumbent position was different between the two techniques: 1.2 ± 3.1mmHg versus 3.5 ± 3.1mmHg, $p = 0.046$ for IAP_{ves} and IAP_{rect}, respectively. Correlation between IAP_{ves} and IAP_{rect} was poor (Table 1). A Bland-Altman analysis for IAP_{rect} versus IAP_{ves} shows a bias of 7.2 mmHg with limits of agreement − 3.5 to 18 mmHg (Fig. 4).

There was a no correlation between $Supine_1$ and $Supine_2$ (Fig. 1) for IAP_{rect} ($r = 0.539$, $p = 0.315$). When repeating the protocol, IAP_{rect} was out of physiological range (> 40mmHg) or unstable in 4/7 patients that were not included for further analysis (57.1%).

Discussion

Correlation between bladder and rectal pressure measurement

Various techniques have been developed to measure IAP, of which the intra-vesical approach is regarded as the gold standard, but it is relatively invasive in an ambulatory setting. There is a need for minimally- or non-invasive techniques of IAP monitoring, especially in obstetrics. IAP estimation via rectal measurements is theoretically appropriate in the pregnant population because of the low-infection risk and lower risk of trauma compared to vesical measurements.

This pilot study found that IAP_{rect} is higher when compared to IAP_{ves}, and IAP differences after position change, or the application of an external abdominal pressure belt, are not similar to the gold standard technique. We also observed a high failure rate in obtaining a reproducible IAP_{rect} measurement.

This study is the first to attempt validation of IAP_{rect} measurements against the gold standard IAP_{ves} in an ICU-setting (9). The inclusion of sedated patients, in whom confounding variables are lower, and the strict protocol are strengths of this study. However, the small sample size and the incompletely performed protocol due to patient issues are weaknesses.

Limitations of rectal pressure measurement

Several factors may affect IAP_{rect} measured via an air-filled balloon. First, previous studies showed that body temperature is higher in the rectum compared to the urinary bladder (19, 20). In the present study a small amount of air (at ambient temperature) was used to fill the rectal balloon and air is very sensitive to temperature changes. The higher rectal temperature will result in an increased air temperature in the balloon. In relation to the constant volume this may lead to a significantly increase in rectal pressure measured via the balloon-tipped catheter. Second, the muscles in the rectum are stronger than the muscles in the urinary bladder. Physiologically, each rectal manipulation and filling stimulates the contraction of the rectal muscles. In a similar way, the insertion and filling of the (even small) balloon could trigger this reflex. Additionally, IAP_{rect} is also affected by the internal anal sphincter tension which contributes about 85% of the pressure in the anal canal (21). Studies in healthy volunteers showed a significant increase in the internal anal sphincter tension followed by an increase in IAP_{rect} after insertion of an artificial manometer for IAP_{rect} measurement (21, 22). Therefore, we can assume that rectal insertion of the T-DOC 7Fr air-filled balloon catheter can increase IAP_{rect} per se.

Third, the high failure rate experienced was largely due to IAP_{rect} measuring values out of the physiological range, or due to difficulties with rectal catheter insertion. These excessive IAP values may be caused by interference from faecal masses or bowel movements on the catheter-tip opening, or an incorrect catheter position at the level of the rectal sphincter. Measuring pressure at the level of the rectal sphincter is used in anorectal manometry but it does not yield information regarding true IAP. Fourth, as pregnant women have an increased risk of constipation and haemorrhoids, therefore, this IAP measurement technique is not suitable to perform in a pregnant population. Laxatives might help to overcome the problem of obstructing stool, however, this is not appropriate in an ambulatory setting. Fifth, although we perceive rectal pressure measurement as being less or even minimal invasive compared to bladder pressure measurement because of the virtual absence of infection risk it must be noted that rectal manipulation can induce parasympathetic hyperactivity with severe bradycardia and cardiac arrhythmias (23).

The results from this pilot study are similar to a study by McCarthy et al., who validated IAP_{rect} in 12 patients but found excessively high or unreliable values in 4 patients (33.3%) due to abdominal traction and technical difficulties on catheter insertion. They concluded that the rectal catheter should be inserted at least 10 cm deep to prevent pressure changes inside the rectum that may result in overestimated readings (24).

Significantly higher IAP_{rect} measurements were observed compared to IAP_{ves}, even when IAP is within the physiological range, and as a result IAP_{rect} over-diagnoses IAH. This is in keeping with IAP_{rect} obtained with a fluid-filled rectal catheter balloon in which residual faecal mass can block the catheter-tip opening leading to overestimation of IAP (9). Correcting this overestimation with a correction factor or the use of a different reference range might not be appropriate as there was no significant correlation between $supine_1$ and $supine_2$. Also, after re-insertion of the rectal catheter, measurement was not repeatable in more than half of the patients. This is in agreement with the results of Lacey et al., who evaluated different indirect techniques against invasive direct IAP measurement in rabbits. Regression analysis showed good correlation with measurements performed in the inferior vena cava (r = 0.87) and the urinary bladder (r = 0.85), but not with intrarectal measurements (r = 0.10) (25). On the contrary, Shafik et al. found IAP_{rect} to be similar to direct IAP measurement (24). Note that IAP_{rect} was measured using a fluid filled rectal catheter.

Effect of body position

Change in body position has a significant impact on IAP measurement. We found that HOB elevation increased both the IAP_{rec} and IAP_{ves}, (Fig. 4) which is in keeping with results from the literature. Previous studies confirmed that even a slight elevation in HOB results in a clinically apparent increase in IAP measured through the bladder (2, 26, 27). Similar investigations were performed to check the impact of body position on IAP measurement not only through the bladder, but also through the stomach (intra-gastric pressure) (28). HOB elevation increases the intra-gastric pressure (IGP) as well as the intra-bladder pressure, however, the IGP changes were observed to a smaller degree compared to IAP_{ves}. In contrast to these studies that have investigated the impact of the upper body position on IAP measurement, the impact of the lower body position on IAP measurement has been assessed recently (29). In this experiment, IAP measurement through the vagina and (in some cases) rectum at supine, low lithotomy, and high lithotomy positions were evaluated. Based on the results of this study, there is no clinically remarkable change in IAP when the legs are position differently. However, the IAP with the patient’s legs in the supine position were lower compared to the low and high lithotomy positions.

Conclusion

This pilot study found that IAP_{rect} is higher when compared to IAP_{ves}. The observed IAP changes induced by position change or the application of an external abdominal pressure belt are not similar when measured via the rectum versus the bladder. IAP_{rect} has important shortcomings making IAP estimation using a rectal catheter unfeasible, largely because the numbers cannot be trusted nor validated.

Abbreviations

IAP Intra-abdominal pressure

IAH Intra-abdominal hypertension

IAP_{ves} Vesicular intra-abdominal pressure

IAP_{rect} Rectal intra-abdominal pressure

HOB Head of bed

FMLV Foley Manometer Low Volume

LOA Limits of agreement

COPD Chronic Obstructive Pulmonary Disease

ICU Intensive care unit

Declarations

Ethics approval and consent to participate

The study was conducted in accordance with the study protocol, the Declaration of Helsinki and applicable regulatory requirements. We applied for approval of the protocol by the local Institutional Review Board and Ethics Committee of the Ziekenhuis Netwerk Antwerpen, ZNA Stuivenberg approved the protocol (EC approval number: 3001 with insurance policy Ethias 45.313.314) and Ziekenhuis Oost-Limburg, Genk, Belgium (EC 12/084U). Oral and written informed consent was obtained from the relatives of all patients. There were no deviations from standard care.

Consent for publication

Consent for publication of figures and manuscript was obtained from the persons involved.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the first author on reasonable request.

Competing interests

MLNGM is a member of the medical advisory Board of Pulsion Medical Systems (now fully integrated in Getinge, Solna, Sweden), Baxter and Serenno Medical (Tel Aviv, Israel), and consults for Maltron, ConvaTec, BD, Spiegelberg and Holtech Medical.

All other authors declare that they have no competing interests in relation to the content published in this manuscript.

Authors' contributions

ASS created the study protocol, performed the measurements, analysed the data, searched for relevant literature and wrote the manuscript.

AH performed the measurements, analysed the data and searched for relevant literature

SC revised the manuscript

NVR edited and revised the manuscript

WG created the study protocol and revised the manuscript

MLNGM created the study protocol, performed the measurements, searched for relevant literature, analysed the data, and revised the manuscript

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philosophy of FOAM (Free Open Access Medical education – #FOAMed).

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Figures

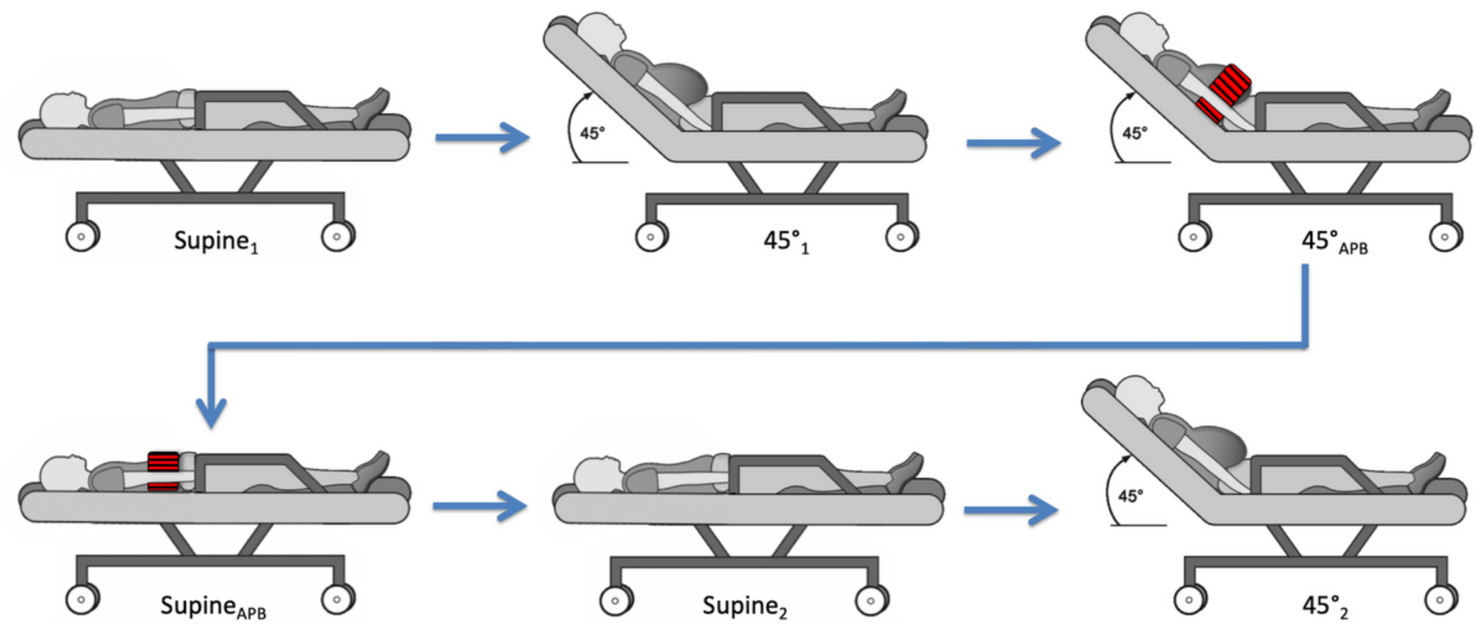

Figure 1

Standardized protocol to measure intra-abdominal pressure

Intra-abdominal pressure measurements were performed in different positions: supine position ($Supine_1$ and $Supine_2$) and 45° semirecumbent ($45°_1$ and $45°_2$) without an external abdominal pressure belt, and 45° semirecumbent ($45°_{APB}$) and supine position ($Supine_{APB}$) with an external abdominal pressure belt (marked with a red spot).

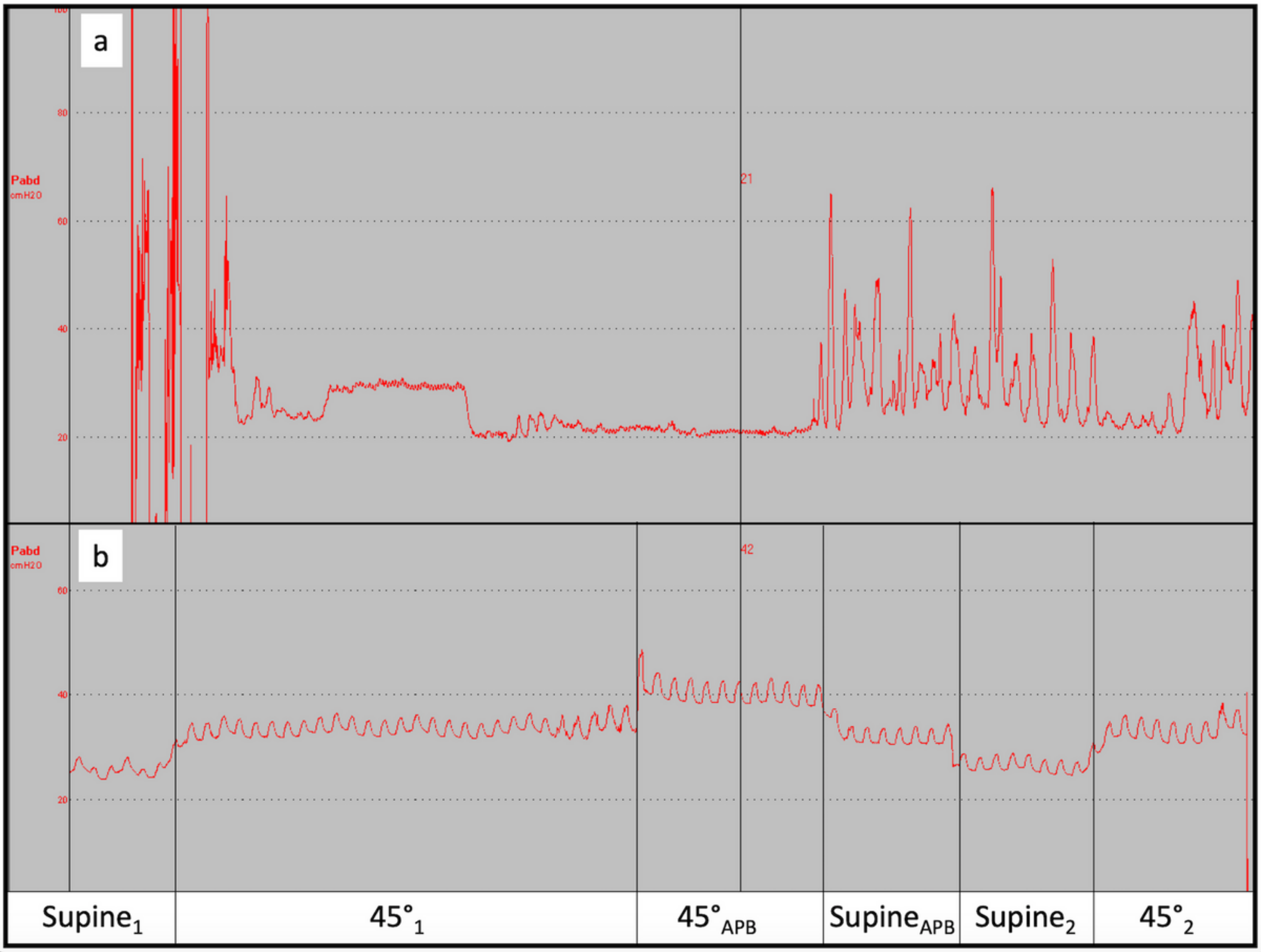

Figure 2

Output of a rectal intra-abdominal pressure measurement

Intra-abdominal pressure measurement in cmH_2O (y-axis) presented over time (x-axis).

(a) invalid measurement due to improper placement of the catheter (first part) and active abdominal muscle contraction (pushing) (last part). (b) valid measurement in which the influence of the breathing is observed: supine position (Supine$_1$ and supine$_2$) and 45° semirecumbent (45°$_1$ and 45°$_2$) without an external abdominal pressure belt, 45° semirecumbent (45°$_{APB}$) and supine position (Supine$_{APB}$) with an external abdominal pressure belt.

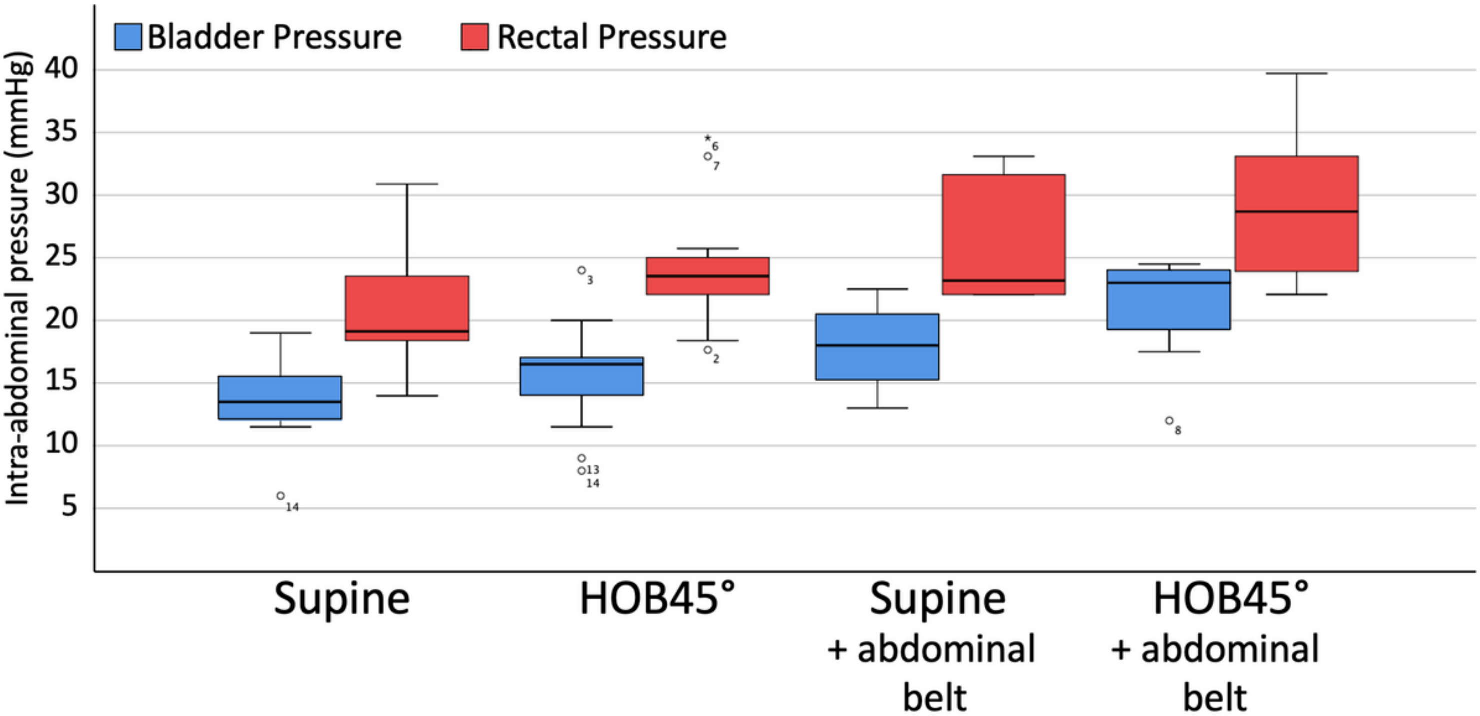

Figure 3

Boxplots comparing vesicular and rectal measurements of intra-abdominal pressure in different body positions

Box and whisker plots comparing IAP_{ves} and IAP_{rect} in different body positions. The error bars are the 95% confidence interval, the bottom and top of the box are the 25th and 75th percentiles, the line inside the box is the 50th percentile (median), and any outliers are shown as open circles.

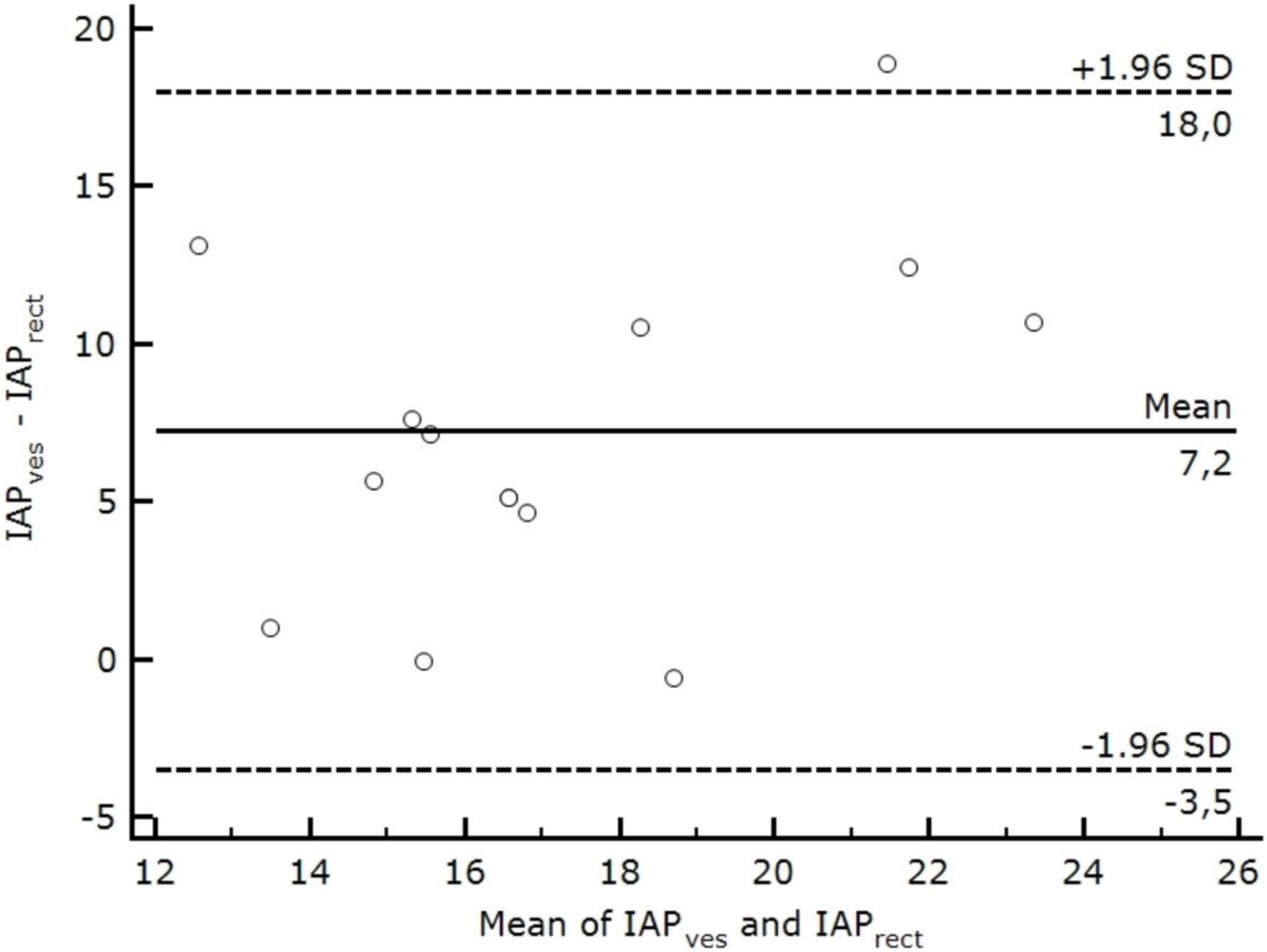

Figure 4

Bland-Altman plot comparing vesicular and rectal measurements of intra-abdominal pressure

Bland and Altman plot for the mean difference between IAP_{rect} and IAP_{ves}, and their 95% limits of agreement. IAP_{rect}: rectal intra-abdominal pressure; IAP_{ves}: vesical intra-abdominal pressure