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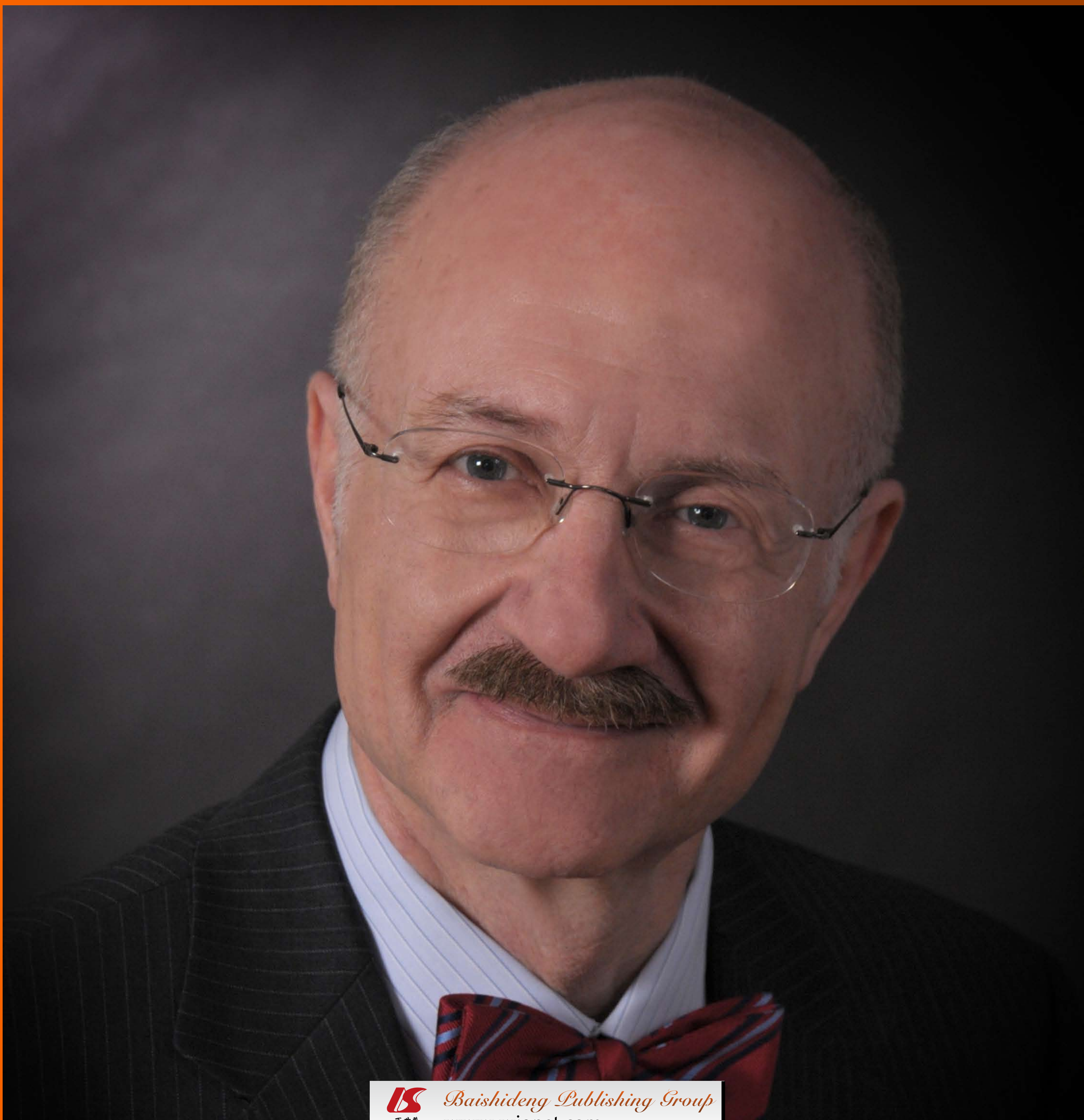

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BRIEF ARTICLE

Effect of intra-abdominal pressure on respiratory function in patients undergoing ventral hernia repair

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Abstract

AIM: To determine the influence of intra-abdominal pressure (IAP) on respiratory function after surgical repair of ventral hernia and to compare two different methods of IAP measurement during the perioperative period.

METHODS: Thirty adult patients after elective repair of ventral hernia were enrolled into this prospective study. IAP monitoring was performed *via* both a balloon-tipped nasogastric probe [intragastric pressure (IGP), CiMON, Pulsion Medical Systems, Munich, Germany] and a urinary catheter [intrabladder pressure (IBP), UnoMeterAbdo-Pressure Kit, UnoMedical, Denmark] on five consecutive stages: (1) after tracheal intubation (AI); (2) after ventral hernia repair; (3) at the end of surgery; (4) during spontaneous breathing trial through the endotracheal tube; and (5) at 1 h after tracheal extubation. The patients were in the complete supine position during all study stages.

RESULTS: The IAP (measured via both techniques) increased on average by 12% during surgery compared to AI (P < 0.02) and by 43% during spontaneous breathing through the endotracheal tube (P < 0.01). In parallel, the gradient between $PaCO_2$ and $EtCO_2$ [$P(a\text{-}et)CO_2$] rose significantly, reaching a maximum during the spontaneous breathing trial. The PaO_2/FiO_2 decreased by 30% one hour after tracheal extubation (P = 0.02). The dynamic compliance of respiratory system reduced intraoperatively by 15%-20% (P < 0.025). At all stages, we observed a significant correlation between IGP and IBP (r = 0.65-0.81, P < 0.01) with a mean bias varying from -0.19 mmHg (2SD 7.25 mmHg) to -1.06 mm Hg (2SD 8.04 mmHg) depending on the study stage. Taking all paired measurements together (n = 133), the median IGP was 8.0 (5.5-11.0) mmHg and the median IBP was 8.8 (5.8-13.1) mmHg. The overall r^2 value (n = 30) was 0.76 (P < 0.0001). Bland and Altman analysis showed an overall bias for the mean values per patient of 0.6 mmHg (2SD 4.2 mmHg) with percentage error of 45.6%. Looking at changes in IAP between the different study stages, we found an excellent concordance coefficient of 94.9% comparing ΔIBP and ΔIGP (n = 117).

CONCLUSION: During ventral hernia repair, the IAP rise is accompanied by changes in $P(a\text{-}et)CO_2$ and PaO_2/FiO_2-ratio. Estimation of IAP *via* IGP or IBP demonstrated excellent concordance.

Key words: Intra-abdominal pressure; Gastric pressure; Bladder pressure; Intra-abdominal hypertension; Hernia; Oxygenation; Respiratory function

Core tip: The surgical repair of ventral hernia is accompanied by a rise of intra-abdominal pressure, a deterioration of CO_2 elimination and a decrease in arterial oxygenation. The measurements of intra-abdominal pressure using nasogastric tube and urinary catheter demonstrate a close agreement between both methods; thus, both these methods can be used in clinical practice.

Gaidukov KM, Raibuzhis EN, Hussain A, Teterin AY, Smetkin AA, Kuzkov VV, Malbrain MLNG, Kirov MY. Effect of intra-abdominal pressure on respiratory function in patients undergoing ventral hernia repair. *World J Crit Care Med* 2013; 2(2): 9-16 Available from: URL: http://www.wjgnet.com/2220-3141/full/v2/i2/9.htm DOI: http://dx.doi.org/10.5492/wjccm.v2.i2.9

INTRODUCTION

Abdominal wall reconstruction during ventral hernia repair can be associated with perioperative intra-abdominal hypertension (IAH), respiratory dysfunction and complications[1-3].

The relationship between intra-abdominal pressure (IAP) and respiratory function was demonstrated for the first time in 1863[3]. Today the negative effects of IAH on respiratory system have been investigated in a large number of studies[2,4]. Development of IAH decreases chest wall compliance and functional residual capacity, shifts the end-expiratory position of the diaphragm, and leads to development of atelectases. Thus, it may affect blood oxygenation and carbon dioxide elimination[2,5]. The abdominal compartment syndrome (ACS) is defined as a sustained increase in IAP exceeding 20 mmHg with the presence of new organ dysfunctions that is associated with significant morbidity and mortality[6-8]. Therefore, in patients with risk factors for IAH it is necessary to measure IAP with simultaneous evaluation of respiratory function[1,9-13].

There are direct and indirect methods for the measurement of IAP[14]. The direct technique involves estimation of IAP through the placement of intraperitoneal catheter. This method however is invasive and thus not applicable in most clinical situations[15]. Many simple and less invasive indirect methods are most often used in routine clinical practice for IAP estimation. These methods include measurement of pressure in hollow organs of the abdomen or pelvis cavity such as bladder, stomach, intestine, and uterus[9,14,16,17]. Among them, the intrabladder technique using Foley catheter has been forwarded as the "gold" standard for IAP estimation in the consensus definitions report of the World Society on Abdominal Compartment Syndrome (WSACS, www.wscas.org)[6,7]. Another indirect technique is the measurement of IAP *via* nasogastric probe[16,18-21].

The increase of the gradient between $PaCO_2$ and $EtCO_2$ [$P(a\text{-}et)CO_2$] can reflect changes in respiratory function. Moreover, the $P(a\text{-}et)CO_2$ value demonstrates an association with dead space volume and severity of pulmonary ventilation-perfusion mismatch due to IAH[5,22]. In 1984, Murray *et al*[23] suggested that $P(a\text{-}et)CO_2$ might be a more sensitive indicator in the search of the optimal positive end-expiratory pressure (PEEP) than changes in lung shunt or PaO_2. Later, it has been shown that monitoring of dead space and $P(a\text{-}et)CO_2$ was useful for detecting lung collapse[24]. In a porcine model of IAH, it has been demonstrated that assessment of $P(a\text{-}et)CO_2$ might help to evaluate the severity of atelectasis during laparoscopic surgery; however these findings still need to be validated in different clinical settings[5].

Today, there are a number of concerns regarding indirect evaluation of IAP. The intrabladder pressure measurements can be unreliable in case of low intrinsic bladder compliance (as in patients with chronic renal failure and anuria), and bladder trauma[9,14,17,25]. The intragastric estimation of IAP can be incorrect during intestinal obstruction with large volume gastric aspirate and partial or total gastric resection[26]. Therefore, these methods need validation in selected categories of patients at risk for IAH.

Thus, the goals of our study were to determine the influence of IAP on respiratory function after surgical repair of ventral hernia and to compare two different methods of IAP measurement during the perioperative period.

MATERIALS AND METHODS

The study was approved by the Medical Ethics Committee of Northern State Medical University, Arkhangelsk, Russian Federation. Written informed consent was obtained from every patient or next of kin.

This prospective study was performed in a 900-bed university hospital (City Hospital#1 of Arkhangelsk). From June 2011 to March 2012, we enrolled 30 adult (age > 18 years) patients (10 males and 20 females) after elective incisional ventral hernia repair, using an open technique. The patients were excluded from the study if they were above 75 years of age, were pregnant or required simultaneous operation, other than ventral hernia repair, or participated in other clinical investigations. Before the procedure all patients received standard premedication with diazepam and omeprazole according to a standard protocol.

All patients received monitoring of IAP *via* both intragastric pressure (IGP) with a balloon-tipped nasogastric probe (CiMON, Pulsion Medical Systems, Germany) and intrabladder pressure (IBP) with a urinary catheter system

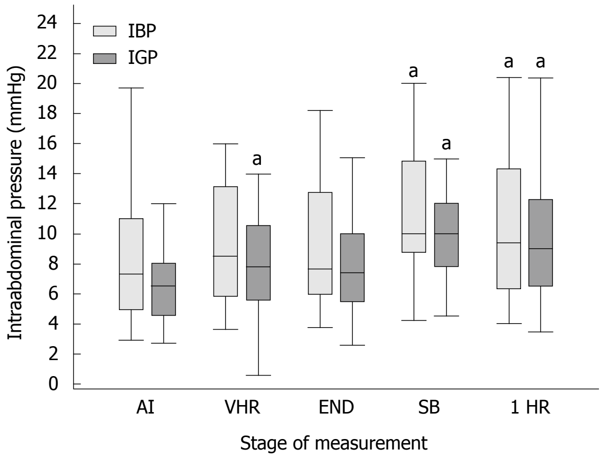

Figure 1 Changes in inintra-abdominal pressure in ventral hernia repair: both methods of measurement are presented. [a]$P < 0.05$ *vs* after tracheal intubation (AI) values using Wilcoxon's signed-rank test with Bonferroni correction. Box plots present median, interquartile interval, and minimum–maximum. VHR: After ventral hernia repair; END: End of surgery; SB: During spontaneous breathing through the endotracheal tube; 1 HR: One hour after extubation; IBP: Intrabladder pressure; IGP: Intragastric pressure.

(UnoMeterAbdo-Pressure Kit, UnoMedical, Denmark). The abdominal perfusion pressure (APP) was calculated by subtracting the IAP from mean arterial pressure for each method of IAP estimation. The measurements also included arterial blood gases (ABL 550, Radiometer, Denmark) and end-tidal CO_2 ($EtCO_2$, Oridion MicroCap, Israel). The combined anesthesia consisted of total intravenous anesthesia (propofol 4-8 mg/kg per hour, fentanyl 0.05-0.1 mg/kg per hour, atracurium 0.2-0.6 mg/kg per hour) and epidural anesthesia at Th 8-10 level (ropivacaine 0.4-0.6 mg/kg). Mechanical ventilation was performed in a pressure-controlled mode (Fabius GS, Dräger, Germany) with FiO_2 0.5, tidal volume 7-8 mL/kg, PEEP 5 cm H_2O and respiratory rate of 12-14/min. After surgery, the level of FiO_2 during data collection was 0.21. The measurements were done during the five consecutive stages: (1) after tracheal intubation (AI); (2) after ventral hernia repair; (3) at the end of surgery; (4) during a spontaneous breathing trial *via* the endotracheal tube; and (5) one hour after tracheal extubation.

Statistical analysis

The SPSS 16.0 software package was used for statistical analysis. We have used non-parametric tests because of small number of observations and non-normal data distribution. Data are presented as a median (25^{th}-75^{th} percentiles). Intragroup comparisons were performed using Wilcoxon signed-rank test. A P-value < 0.05 was considered as significant. For multiple comparisons, we used Bonferroni correction. The Spearman correlation coefficient (*rho*) and Bland-Altman analysis were used to determine the agreement between the two techniques of IAP measurement and to calculate the percentage error. We compared the mean values with SD per patient (n = 30) and computed the Pearson correlation coefficient. Two methods may be used interchangeably if r^2 (Pearson correlation coefficient) is > 0.6, if the differences between bias and limits of agreement (1.96 SD) are not clinically important and if the percentage error is less than 35%. Finally, the ability of IGP to track changes or trends in IBP was assessed by plotting ΔIBP against ΔIGP during the same time interval (four quadrants trend plot). The concordance coefficient is calculated as the percentage of pairs with the same direction of change. Based on clinical relevance, the concordance should be > 90% when pairs with both a ΔIBP and ΔIGP $\leqslant \pm$ 2.5 mmHg are excluded for analysis.

RESULTS

The median age was 61 (53-69) years, weight 89 (73-103) kg, and body mass index (BMI) 31 (29-36) kg/m^2, respectively. The median size of incisional hernia was 244 (170-415) cm^2. The fluid balance for the first day after operation was 1700 (1325-2000) mL. According to both techniques of measurement, during surgery IAP increased on average by 12% from AI (P = 0.013 and P = 0.002 for IBP and IGP, respectively; Figure 1). The maximal increase of IAP by 43% was observed during spontaneous breathing through the endotracheal tube: up to 10 (9-15) mmHg for IBP and 10 (8-12) mmHg for IGP (P = 0.001). At the end of the investigation, IAP still exceeded the AI values (P = 0.003 and P = 0.006 for IBP and IGP, respectively). The abdominal perfusion pressure (APP), blood gases ($PaCO_2$ and $EtCO_2$) and arterial lactate concentrations are presented in Table 1. The values of APP rose significantly after transfer to spontaneous breathing (P < 0.001 for both IBP and IGP) in parallel with the increase in $PaCO_2$ and $EtCO_2$ (P < 0.013). The gradient between $PaCO_2$ and $EtCO_2$ also rose significantly reaching a peak during spontaneous breathing trial (P = 0.02) (Figure 2A). The mean arterial lactate concentration did not change significantly and did not exceed 1 mmol/L throughout the study.

The oxygenation index (PaO_2/FiO_2) was decreased by 30% one hour after tracheal extubation (P = 0.02 *vs* AI; Figure 2B). These changes were delayed as compared to the increase of IAP and P(a-et)CO_2.

Tidal volume during the study did not change significantly (not shown). However, the dynamic compliance of the respiratory system decreased with 15%-20% both after hernia repair and at the end of surgery (P < 0.025; Table 1).

At all stages, we found a significant correlation between the two methods of IAP measurement (r = 0.65-0.81, P < 0.01). The mean bias between gastric and urinary methods of IAP monitoring varied during the study from -0.19 mmHg (2SD 7.25 mmHg) to -1.06 mmHg (2SD 8.04 mmHg) (Table 2). Taking all paired measurements together (n = 133), the median IGP was 8.0 (5.5-11.0) mmHg and the median IBP was 8.8 (5.8-13.1) mmHg. In total, 4 outliers, related to measurement error, or abdominal muscle contraction or migrating motor complex activity (2 paired measurements each in 2

Table 1 Changes in abdominal perfusion pressure, blood gases, arterial lactate and dynamic compliance during different study stages

Study stage	AI	VHR	END	SB	1 HR
APP = MAP - IBP	75 (63-82)	74 (66-85)	82 (68-96)	92 (77-98)[a]	85 (77-96)[a]
APP = MAP - IGP	74 (65-82)	78 (67-85)	74 (65-82)	90 (78-97)[a]	85 (77-96)[a]
$PaCO_2$ (mmHg)	36 (34-39)	36 (33-42)	37 (34-42)	40 (38-49)[a]	37 (35-40)
$EtCO_2$ (mmHg)	32 (29-35)	30 (27-35)	33 (28-36)	36 (31-39)[a]	33 (30-35)
Arterial lactate (mmol/L)	0.9 (0.7-1.0)	0.7 (0.6-0.8)	0.8 (0.7-1.0)	1.0 (0.7-1.4)	0.9 (0.8-1.4)
Dynamic compliance (mL/cm H_2O)	32 (26-38)	27 (22-32)[a]	26 (22-30)[a]		

Data are presented as median and interquartile interval. [a]P < 0.05 *vs* AI values using Wilcoxon's signed-rank test with Bonferroni correction. AI: After intubation; VHR: After ventral hernia repair; END: End of surgery; SB: During spontaneous breathing through the endotracheal tube; 1 HR: One hour after extubation; APP: Abdominal perfusion pressure; MAP: Mean arterial pressure; IBP: Intrabladder pressure, IGP: Intragastric pressure; $PaCO_2$: Partial pressure of carbon dioxide in arterial blood; $EtCO_2$: End-tidal partial pressure of carbon dioxide.

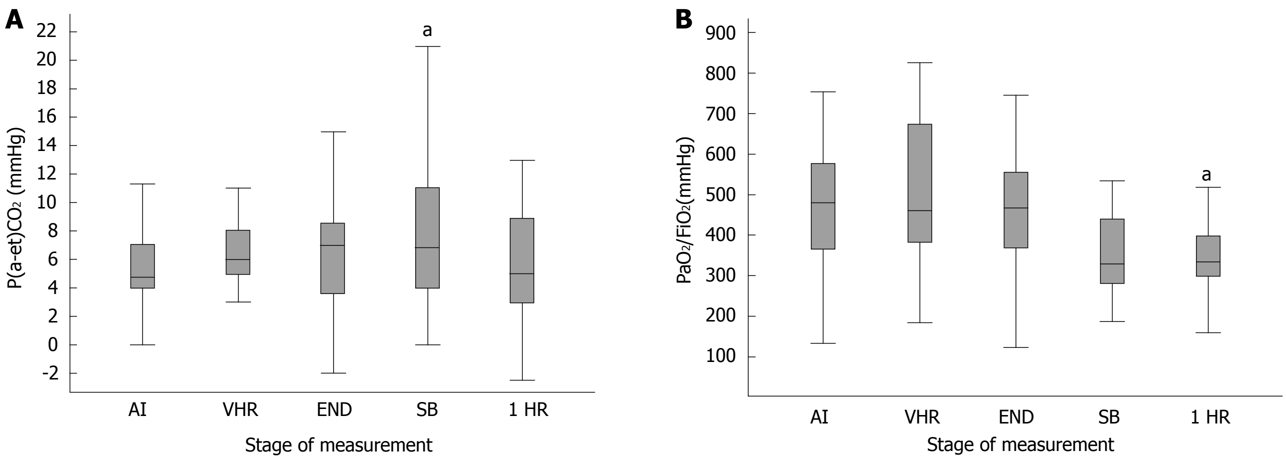

Figure 2 Changes in arterial to end-tidal CO_2 gradient (A) and oxygenation index (PaO_2/FiO_2) (B) during and after ventral hernia repair. [a]P < 0.05 *vs* after tracheal intubation (AI), Wilcoxon's signed-rank test. Box plots present median, interquartile interval, and minimum-maximum. VHR: After ventral hernia repair; END: End of surgery; SB: During spontaneous breathing through the endotracheal tube; 1 HR: One hour after extubation.

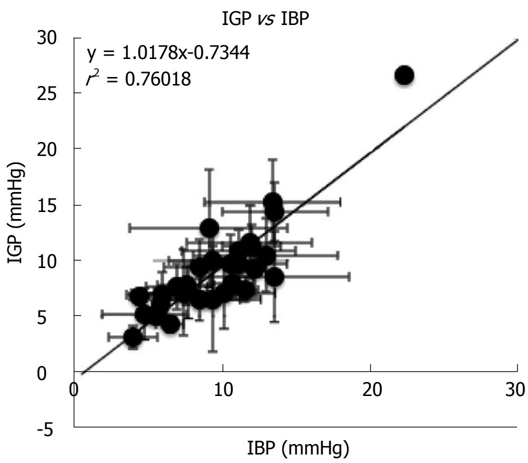

Figure 3 Regression analysis of intrabladder and intragastric pressure. Patient averages (n = 30) with mean ± SD deviation of intrabladder pressur (IBP) and intragastric pressure (IGP).

patients) were excluded from further analysis. Pearson correlation coefficient comparing mean IBP and IGP values (n = 30) showed a r^2 of 0.76 (P < 0.0001). Figure 3 demonstrates the regression analysis between mean IBP and IGP values per patient. Bland-Altman analysis of all paired measurements (n = 128) showed an overall bias of -0.7 ± 2.9 mm Hg (with limits of agreement from -6.6 to 5.2 mmHg) with percentage error of 65.5% (Figure 4A). When analyzing the mean values per patient (n = 30), we found an overall bias of 0.6 ± 2.1 mm Hg (with limits of agreement from -3.7 to 4.8 mm Hg) with percentage error of 45.6% (Figure 4B). Concordance correlation coefficients of the IAP measurements during the study are shown in Table 3. The precision and accuracy of IAP measurements during study stages varied within 0.63-0.85 and 0.95-0.98, respectively. The four quadrants trend plot is shown in Figure 5. From the 117 initial paired measurements, 55 pairs were excluded because either ΔIBP or ΔIGP were ≤ ± 2.5 mmHg or because ΔIBP or ΔIGP were equal to zero. The calculated level of concordance was 94.9%.

DISCUSSION

This study demonstrates that the increase in IAP during surgical repair of ventral hernia and the early postoperative period is accompanied by deterioration of CO_2 elimination followed by a decrease in arterial oxygenation. These

Table 2 Agreement between the two techniques of intra-abdominal pressure measurement

	Number of patients	Mean intra-abdominal pressure	Correlation analysis		Bland–Altman analysis	
			r	*P*	bias	Precision
After tracheal intubation	29	7.83	0.65	0.002	-1.06	4
After ventral hernia repair	28	9.22	0.73	0.001	-0.57	2.8
At the end of surgery	26	8.91	0.75	0.001	-0.46	4.1
During spontaneous breathing through the end of tracheal tube (spontaneous breathing trial)	23	11.48	0.75	0.002	-0.19	3.6
At 1 h after tracheal extubation	27	9.7	0.81	0.001	-1.00	3.3

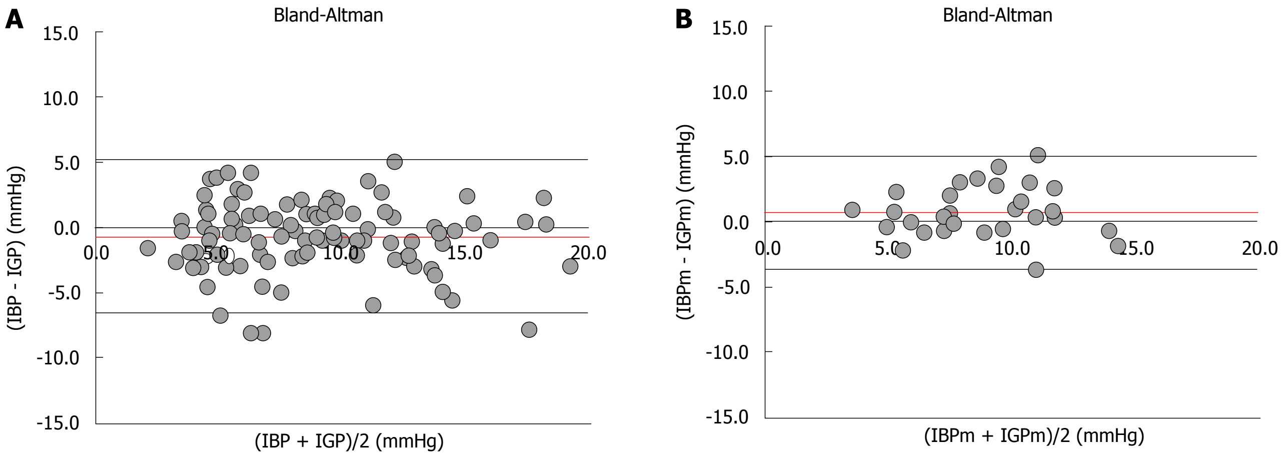

Figure 4 Bland-Altman analysis of all paired measurements (*n* = 128, A) and of paired measurements of mean intrabladder pressure and mean intragastric pressure (*n* = 30, B). IBP: Intrabladder pressure; IGP: Intragastric pressure; IBPm: Mean intrabladder pressure; IGPm: Mean Intragastric pressure.

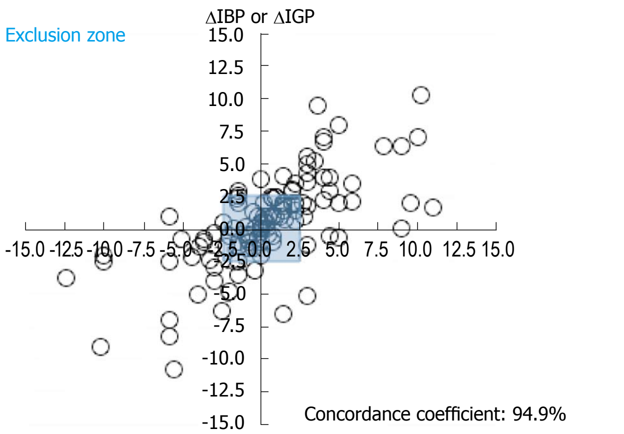

Figure 5 Four quadrants trend plot. Plot for 117 paired measurements of ΔIBP and ΔIGP. From the 117 initial paired measurements, 55 pairs were excluded because either ΔIBP or ΔIGP were ≤ ± 2.5 mmHg or because ΔIBP or ΔIGP was equal to zero (exclusion zone). The calculated level of concordance was 94.9%. See text for explanation. IBP: Intrabladder pressure; IGP: Intragastric pressure.

changes reflect the impairment of respiratory function after the procedure and could guide possible interventions.

The rise in IAP during abdominal surgery observed in our study can be explained by the stretch of abdominal wall following hernia repair[3,26]. The peak of IAP increase was observed during spontaneous breathing after reversal of the effects of muscle relaxants and sedative agents[11,26,27]. Despite the rise in IAP, APP remained above 60 mmHg during all study stages, and this was accompanied by normal arterial lactate concentrations, reflecting adequate organ perfusion[9,28]. Previous studies considered an APP < 60 mmHg to be the indicator of abdominal hypoperfusion, moreover, APP has been shown to correlate well with survival from IAH and ACS[29,30].

The increase in IAP during and after repair of ventral hernia together with effects caused by general anesthesia can lead to deterioration of respiratory function. Thus, the rise in $PaCO_2$, $EtCO_2$ and $P(a\text{-}et)CO_2$ in parallel with reduction in respiratory compliance in our study may be caused by atelectasis formation in the basal lung areas, although we did not perform radiological imaging. The increase of the CO_2 gradient can occur when mixed venous blood passes the pulmonary circulation through shunt vessels without delivering CO_2 to alveolar air that is typical for atelectasis. Moreover, when ventilated lung areas are compromised by the cranial displacement of the diaphragm caused by IAH, a shift of ventilation can be anticipated so that regions ventilated normally before the insult are becoming over-ventilated in relation to their perfusion[5].

In addition, increased $P(a\text{-}et)CO_2$ can result from a decrease of cardiac output. The linear relationship between changes in $EtCO_2$ and cardiac output observed in animals has supported the necessity of clinical studies

Table 3 Concordance between the two intra-abdominal pressure measurements during different study stages

	All measurements	AI	VHR	END	SB	1 HR
Number of measurements	133	29	28	26	23	27
Concordance correlation coefficient	0.74	0.61	0.84	0.62	0.81	0.69
95%CI	0.65-0.80	0.33-0.79	0.69-0.92	0.34-0.80	0.63-0.90	0.45-0.84
Precision	0.75	0.63	0.85	0.65	0.84	0.73
Accuracy	0.98	0.96	0.98	0.95	0.96	0.95

Precision: Pearson's correlation coefficient; Accuracy: bias correction factor; AI: After intubation; VHR: After ventral hernia repair; END: End of surgery; SB: During spontaneous breathing through the endotracheal tube; 1 HR: One hour after extubation.

to determine whether a change in $EtCO_2$ would be useful as a noninvasive, continuous indicator of a change in cardiac output during anesthesia or intensive care[31]. In line with this hypothesis, McSwan *et al*[32] have shown that the $P(a-et)CO_2$ gradient increased in parallel with a rise in physiologic dead space (Vd). It is known that poor pulmonary perfusion from low cardiac output or hypotension can elevate Vd fraction[33] due to peripheral carbon dioxide production, which increases $P(a-et)CO_2$ in case of a persistent decreased blood flow[34].

In spite of decreased cardiac output as one of the reasons for the rise in $P(a-et)CO_2$, we suggest that the pivotal role in this process belongs to atelectasis formation. This speculation is confirmed by the delayed deterioration of arterial oxygenation in relation to the increase of IAP and $P(a-et)CO_2$. Similar findings were obtained by Strang *et al*[5]. During atelectasis formation, even a transient increase in PaO_2 might occur, due to a decreased intrapulmonary shunt (Qs/Qt). Consequently, oxygenation may not adequately reflect the severity of lung collapse during IAH[5], and hypoxemia usually develops later than changes in CO_2. The decrease in PaO_2/FiO_2 and atelectasis after the hernia repair may also be related to discontinuation of PEEP following extubation. Thus, Pelosi *et al*[2] recommended the application of PEEP to prevent atelectasis formation related to IAP in morbidly obese patients during general anaesthesia.

The difference between gastric and urinary methods of IAP estimation observed in our study may be caused by the physical characteristics of the wall of bladder. This wall is not merely a membrane that transfers pressure from the intra-abdominal space to the bladder content[14,16,17]. Bladder wall compliance differs between patients and depends on several factors such as age, presence of chronic renal failure, BMI, filling status, fluid balance and bladder perfusion/ischemia. Moreover, several patients in our study had peritoneal adhesions, which might limit the transduction of abdominal pressure during measurement. Thus, IAP measured at one point cannot always be considered to be the pressure in the whole abdominal cavity[16, 25,35]. Body anthropomorphic data may also have an impact on IAP measured at different sites[36,37]. We found that the measurement of IAP through the nasogastric probe correlates well with the results of the intrabladder measurement with mean difference between methods around -0.7 mmHg (with IGP being consistently lower than IBP). However, the mean percentage error of all measurements of IAP was 45.6%, thus in ventral hernia repair, both methods for the estimation of IAP can be used interchangeably keeping in mind the possibility of large data variations and the limitations of monitoring techniques. Moreover, both methods were able to keep track of changes in IAP during the different study stages as demonstrated by the concordance coefficient above 90%. In addition, Malbrain *et al*[16] concluded that in some patients, IAP estimation *via* nasogastric probe and IAP estimation *via* urinary catheter may differ significantly and this may have clinical implications. This situation can occur due to localized ACS, thus clinicians should be aware of this possibility. In order to identify risk factors and to recommend treatment for localized ACS, further studies of simultaneous intragastric and intrabladder IAP measurements are needed. In conclusion, this study fulfilled the minimal requirements for IAP measurement and validation studies as suggested by the "Recommendations for research by the International Conference of Experts on Intra-abdominal Hypertension and Abdominal Compartment Syndrome"[38]. More than 20 relevant patients were included with a broad range of IAP from normal to high. At least 50% of the measurements demonstrated IAP $\geqslant$ 12 mmHg and at least some measurements an IAP > 20 mmHg (5%). When looking at the mean values per patient, the bias was $\leqslant$ 1 mmHg with a precision close to 2 mmHg, good accuracy, reasonable limits of agreement and excellent concordance.

The surgical repair of ventral hernia is accompanied by a rise IAP and a parallel increase of $PaCO_2$, $EtCO_2$, and arterial to end-tidal gradient of CO_2, followed by a decrease in arterial oxygenation. The measurements of IAP using nasogastric tube and urinary catheter demonstrate a close agreement between both methods with excellent concordance, although the percentage error was quite high suggesting that the abdomen may not always act like a fluid filled compartment. Thus, both these methods can be used in clinical practice.

COMMENTS

Background

Abdominal wall reconstruction during ventral hernia repair can be associated with perioperative intra-abdominal hypertension (IAH), respiratory dysfunction and complications.

Research frontiers

The methods for measuring intra-abdominal pressure (IAP) are integrating in clinical practice but need validation in selected categories of patients at risk for IAH, including ventral hernia surgery.

Innovations and breakthroughs

The measurement of IAP through the nasogastric probe during hernia repair and postoperative period correlates well with the results of the intra-bladder measurement.

Applications

The study findings reflect the impairment of respiratory function after the surgery for ventral hernia that requires possible interventions, including measurement of IAP and correction of IAH.

Terminology

Intra-abdominal pressure: pressure in hollow organs of the abdomen or pelvis cavity such as bladder, stomach, intestine, and uterus. Intra-abdominal hypertension: intra-abdominal pressure exceeding 12 mmHg.

Peer review

The paper determined the influence of IAP on respiratory function after surgical repair of ventral hernia and compared two different methods of IAP measurement during the perioperative period. It's very well done study.

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