Available online at www.medicinescience.org

ORIGINAL ARTICLE

Medicine Science International Medical Journal

Medicine Science 2020;9(3):774-8

The effect of lower intra-abdominal pressure on intracranial pressure measured by optic nerve sheath diameter during laparoscopic surgery

Duygu Kara[1], Cafer Mutlu Sarikas[2]

[1]*Adnan Menderes University, Medical Faculty, Department of Anesthesiology and Reanimation, Aydin, Turkey*
[2]*Erzurum Regional Training and Research Hospital, Department of Anesthesiology and Reanimation, Erzurum, Turkey*

Received 13 January 2020; Accepted 03 April 2020
Available online 27.08.2020 with doi: 10.5455/medscience.2020.09.9226

Abstract

The aim of this study was to show different optic nerve sheath diameters (ONSD) using ultrasonography under different intra-abdominal pressures (IAPs) and to investigate the association between intracranial pressure (ICP) elevation and perioperative hemodynamic parameters. One hundred patients aged 18-80 years with ASA scores I&II were included. All patients received the same anesthesia protocol and were divided into two groups depending on their IAP, Group A (10 mmHg) and Group B (15 mmHg). ONSD, peak (Ppeak) and plateau (Pplateau) airway pressures, end-tidal volume carbon dioxide ($ETCO_2$), heart rate (HR), and mean arterial blood pressure (MAP) were measured before pneumoperitoneum (T_0), at the 10th minute of pneumoperitoneum (T_1), and at the end of pneumoperitoneum (T_2). No differences were determined between the groups in terms of age, gender, anthropometric measurements, ASA scores, underlying disorders, or duration of pneumoperitoneum, surgery, and anesthesia. Group B patients had higher ONSD values at T_2 than Group A (5.0±0.2 vs 5.2±0.2) ($p<0.001$). MAP at T_2 was higher in Group B than in Group A (91.5±9.5 vs 98.4±12.0) ($p=0.001$). HR values were higher in Group A than Group B at all time points ($p<0.001$, $p<0.001$, and $p=0.001$, respectively). Ppeak, Pplateau, and $ETCO_2$ values at T_1 and T_2 were higher in Group B than Group A. The results of this study revealed that IAP affects ONSD, MAP, HR, Ppeak, Pplateau, and $ETCO_2$. ONSD increased from commencement of pneumoperitoneum. Higher IAP resulted in higher ONSD, and thus in increased ICP, which should be noted by surgeons and anesthesiologists.

Keywords: Intra-abdominal pressure, optic nerve sheath diameter, laparoscopic surgery

Introduction

Laparoscopic surgery is a widely used and comfortable technique. It reduces bleeding and pain, and results in shorter hospital stays and improved cosmetic outcomes. During laparoscopic procedures, iatrogenically induced pneumoperitoneum is established in the peritoneal cavity. This permits a sufficient workspace for performing surgical tasks with satisfactory patient and surgeon safety. The normal resting abdominal cavity pressure is between 5 and 7 mmHg in the supine position. However, inflating the abdominal cavity beyond its compliance of capacity results in increased intra-abdominal pressure (IAP), leading to problems such as reduction in blood flow, perfusion, and urinary output and causing hypoxia, ischemia, and increased oxidative stress [1]. Additionally, it is associated with elevated intracranial pressure (ICP), which is exacerbated by use of the steep Trendelenburg position [2].

The optic nerve sheath diameter (ONSD) is a reliable indicator for monitorization of intracranial pressure. Each 1-mmHg rise in the partial pressure of CO_2 causes a rise of 1.8 mL/100 mg/minin cerebral blood flow [3]. In addition, CO_2 absorption increases with retroperitoneal dissection. Elevated ICP results in decreased cerebral perfusion pressure. This causes ischemia in the brain parenchyma and delayed recovery from anesthesia. The optic nerve is the outer part of the embryogenic diencephalon. Its nerve sheath also derives from the meninges, and the cerebrospinal fluid travels between the intracranial and intraorbital subarachnoid spaces. ONSD has been shown to be well correlated with ICP [4]. Sonographic measurement of ONSD is a simple, safe, non-invasive, and reliable method for reflecting ICP [5]. ONSD can therefore be a surrogate parameter for measuring ICP.

The purpose of this study was to measure ONSD using ultrasonography during different IAP values and to compare these values, and thus ICP, with perioperative hemodynamic complications.

Materials and Methods

One hundred patients aged 18-80, scheduled for laparoscopic cholecystectomy surgery, and with ASA (American Society of Anesthesiologists) scores of I and II between 01/01/2017 and 12/31/2018 were prospectively enrolled. Eligible patients were randomized based on presentation to the surgery. Patients' age, sex, anthropometric measurements (weight, height, and body mass index), ASA type, and underlying disorders were recorded.

***Corresponding Author:** Duygu Kara, Adnan Menderes University, Medical Faculty, Department of Anesthesiology and Reanimation, Aydin, Turkey, E-mail: drduygukara@yahoo.com

The duration of pneumoperitoneum, surgery, and anesthesia were also noted.

The local ethical committee (Erzurum Regional Training and Research Hospital) approved the study. ONSD, Peak airway pressure (Ppeak), Plateau pressure (Pplateau), end-tidal volume carbon dioxide ($ETCO_2$), heart rate (HR), and mean arterial blood pressure (MAP) were measured

i) Before pneumoperitoneum (T_0)

ii) At the 10th minute of pneumoperitoneum (T_1) and

iii) At the end of pneumoperitoneum (T_2)

Patients received the same anesthetic protocol and were divided into two groups. Patients with intra-abdominal pressure (IAP) of 10 mmHg constituted Group A, and those with IAP of 15 mmHg constituted Group B. The two groups were then compared in terms of patient and surgery characteristics, and of Ppeak, Pplateau, $ETCO_2$, HR, MAP, and ONSD.

Patients younger than 18, pregnant women, and patients with any ophthalmological disease affecting optic nerve diameters or receiving any treatment affecting cerebrospinal fluid pressure were excluded.

IAP was maintained and measured via a laparoscopic insufflator with high-pressure nozzles directing CO_2 into the cannula until the desired IAP of 10 or 15 mmHg was achieved. A continuous flow circuit was set to detect minor changes in IAP in real time and to adjust the flow, by insufflating more gas in or evacuating excess to keep the IAP stable.

ONSD was measured with the patient in the supine position using an iU22 ultrasound system (Philips) in B-mode and its 9-3 MHz linear array transducer. Following application of ultrasonography gel, bilateral gentle measurements were performed with probes on the closed upper eyelids. All eyes were examined twice, and the average of all measurements was recorded. A diameter less than 5 mm is generally regarded as normal. Diameters exceeding 5.5 mm can predict an ICP of ≥20 cm H_2O with 100% sensitivity and specificity [6].

Statistical analyses

Mean, standard deviation, median, minimum, maximum, frequency, and ratio values were used during the statistical analyses. The distribution of the variables was checked with the Kolmogorov-Smirnov test. Analyses of independent quantitative variables were performed using the T-test and the Mann-Whitney U test, while Wilcoxon's test was used for dependent quantitative variables. Qualitative independent variables were analyzed using the chi-square test. Analyses were performed on SPSS version 22.0 software.

Results

The mean age of the patients was 48.0±12.2 years, and the majority were women (78/22). Fifty-two patients had ASA scores of I. Twenty-three patients had hypertension (23%), 19 (19%) diabetes mellitus, and one (1%) had chronic obstructive pulmonary disease. Table 1 shows the other characteristics of the study population.

Table 1. Patient and surgery characteristics, and study parameters

Patient properties	Mean ± standard deviation
Body weight, kg	77.6±10.9
Height, cm	160±0.1
Body mass index	28.8±4.0
Surgical properties, minutes	
Duration of pneumoperitoneum	33.3±10.7
Duration of surgery	45.3±10.7
Duration of anesthesia	58.0±12.0
Mean arterial blood pressure, mmHg	
T_0	86.7±9.8
T_1	90.0±10.0
T_2	95.0±11.3
Heart rate, (beats/minute)	
T_0	78.5±10.2
T_1	78.3±9.8
T_2	78.4±8.8
Optic nerve sheath diameter, mm	
T_0	4.6±0.1
T_1	5.0±0.2
T_2	5.1±0.2
Ppeak, cmH_2O	
T_0	16.5±1.2
T_1	21.7±2.9
T_2	23.0±3.5
Pplateau, cmH_2O	
T_0	14.7±1.2
T_1	19.4±3.0
T_2	21.2±3.6
End tidal carbon dioxide, mmHg	
T_0	31.6±1.2
T_1	33.3±1.3
T_2	34.7±1.6

T_0, before pneumoperitoneum; T_1, at the 10th minute of pneumoperitoneum; T_2, at the end of pneumoperitoneum

No statistically significant difference was observed between groups A and B in terms of age, gender, anthropometric measurements, ASA scores, underlying disorders, or duration of pneumoperitoneum, surgery, and anesthesia.

Optic nerve sheath diameter

While T0 and T1 were similar between the groups, Group B had statistically significantly higher ONSD values than Group A at T_2 (5.0±0.2 vs 5.2±0.2) ($p<0.001$) (Table 2). The differences between T_0/T_1, T_0/T_2, and T_1/T_2 were higher in Group B than in Group A (p=0.001, p<0.001, and p<0.001, respectively). Additionally, all the intragroup differences, such as differences between T_0/T_1, T_0/T_2, and T_1/T_2 in both groups, were significantly different (p<0.001 for each).

Table 2. Differences in optic nerve sheath diameters between the groups

	Group A	Group B	p value
T_0	4.6±0.2	4.6±01	0.1
T_1	4.9±0.2	5.0±0.2	0.06
T_2	5.0±0.2	5.2±0.2	**<0.001***
Difference between T_0/T_1	0.3±0.1	0.4±0.2	**0.001***
Intragroup difference, p value	**<0.001***	**<0.001***	
Difference between T_0/T_2	0.4±0.1	0.7±0.2	**<0.001***
Intragroup difference, p value	**<0.001***	<0.001	
Difference between T_1/T_2	0.1±0.1	0.3±0.1	**<0.001***
Intragroup difference, p value	**<0.001***	**<0.001***	

Group A, patients with intra-abdominal pressure of 10 mmHg; Group B, patients with intra-abdominal pressure of 15 mmHg
T_0, before pneumoperitoneum; T_1, at the 10th minute of pneumoperitoneum; T_2, at the end of pneumoperitoneum
Values expressed as millimeters and mean±standard deviation
*, statistically significant

Mean arterial blood pressure

While no difference was determined between the groups at T0 and T_1, MAP at T_2 was statistically significantly higher in Group B than in Group A (91.5±9.5 vs 98.4±12.0) (p=0.001) (Figure 1). While the difference in T_0/T_1 was similar between the groups, the differences in T_0/T_2, and T_1/T_2 were higher in Group B than in Group A (p<0.001 and p=0.002). In addition, analysis of the differences within Group A revealed that MAP values at T_1 and T_2 were both greater than at T_0 (p=0.03 and p=0.003, respectively), while MAP values at T_1 and T_2 were not significantly different between the groups.

In Group B, MAP values at T_1 and T_2 were both greater than at T_0 (p=0.04 and p<0.001, respectively). Moreover, MAP at T_2 was higher than at T_1 (p<0.001).

Heart rate

HR values were higher in Group A than in Group B at all time points (p<0.001, p<0.001, and p=0.001, respectively) (Figure 1). Nevertheless, the differences between T_0/T_1, T_0/T_2, and T_1/T_2 were similar between groups B and A. In addition, none of the intragroup differences between the time intervals differed significantly in either group.

Ppeak value

T_0 values were similar between the groups, but Ppeak at T^1 was significantly higher in Group B than in Group A (19.7±1.7 vs. 23.6±2.6). Ppeak at T_2 was also higher in Group B than in Group A (20.1±1.5 vs. 25.9±2.3) (p<0.001, for both) (Figure 2). The differences between T_0/T_1, T_0/T_2, and T_1/T_2 were higher in Group B than in Group A (p<0.001 for each). Additionally, all intragroup differences in both groups were statistically significant, similarly to ONSD (p<0.001 for each).

Pplateau values

T_0 Pplateau values were similar between the groups. Pplateau at T_1 was significantly higher in Group B than in Group A (18.1±1.8 vs. 20.7±3.4), and was higher in Group B than in Group A at T_2 (18.1±1.5 vs. 24.4±2.1) (p<0.001, for both) (Figure 2). The differences between T_0/T_1, T_0/T_2, and T_1/T_2 were higher in Group B than in Group A (p<0.001 for each). Additionally, all intragroup differences in both groups were statistically significant, except for T_1/T_2 in Group A (p<0.001 for each).

End tidal carbon dioxide

T_0 values were similar between the groups. $ETCO_2$ values at T1 were significantly higher in Group B than in Group A (32.8±1.2 vs. 33.7±1.3), and also at T_2 (33.8±1.4 vs. 35.5±1.2) (p=0.002 and p<0.001) (Figure 2). The differences between T_0/T_1, T_0/T_2, and T_1/T_2 were higher in Group B than in Group A (p<0.001 for each). Additionally, all intragroup differences in both groups were statistically significant (p<0.001 for each).

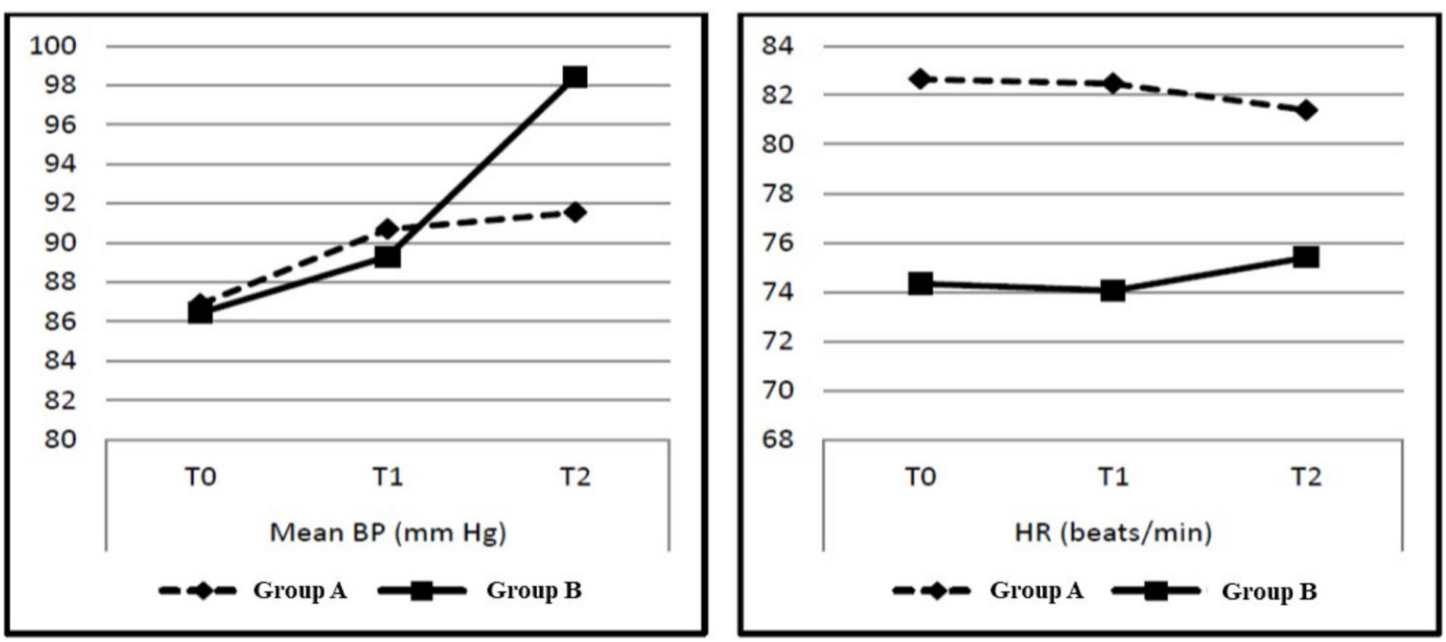

Figure 1. Mean arterial blood pressure and heart rate variations in the study groups

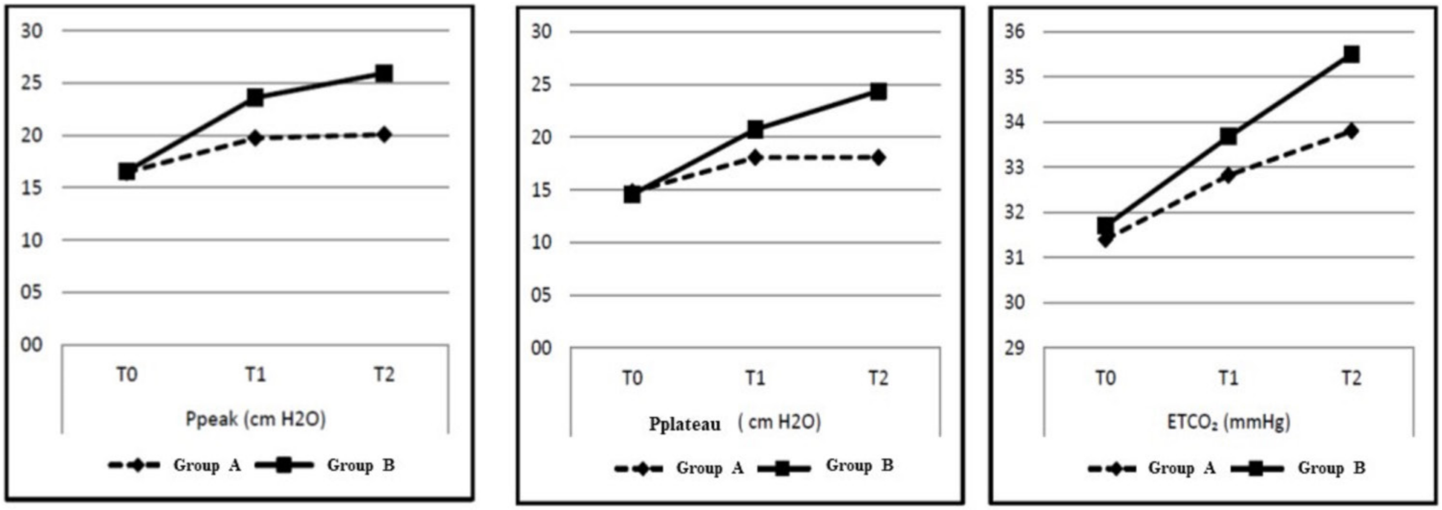

Figure 2. Peak and plateau pressures and end tidal volume variations in the study groups

Discussion

Laparoscopic surgery is a commonly employed method for the surgical correction of most intra-abdominal pathologies, as it is minimally invasive and involves fewer intra- and postoperative complications. However, pneumoperitoneum with concurrent intra-abdominal CO_2 insufflation is associated with decreased cerebral perfusion pressure and increased ICP [7]. In the present study, patients with higher IAP had higher ONSD values at the end of the surgical procedure. In addition, ICP and insufflation pressure exhibited a linear relationship. ONSD values increased in a time-dependent manner in both groups, and the incremental trend observed until the end of surgery was more prominent in patients with higher IAP. Similarly, Dip et al. [8] showed that acute elevation in IAP during laparoscopy significantly increased ONSD. The changes in the ONSD reflect a temporary and reversible increase in ICP due to the acute elevation of IAP throughout surgery. The Abdominal Compartment Society defines a pneumoperitoneum at ≥12 mmHg as abdominal hypertension [1]. The patients in Group B in the present study can therefore be regarded as having abdominal hypertension, and these also exhibited more pronounced ONSD. A recent study showed similar elevations in ONSD throughout pneumoperitoneum during obesity surgery [9]. Sujata et al. [3] reported positive correlation between duration of surgery and the maximum rise in ONSD in patients given sevoflurane-maintained anesthesia. However, we found no association with duration of surgery between the groups. In addition to lumbar venous plexus compression and hypercarbia, inferior vena cava compression also contributes to the inhibition of cerebral venous drainage during pneumoperitoneum. Similarly to alleviation with abdominal decompression, lower IAP may relieve elevated ICP [10].

Elevated IAP is transmitted to the thoracic compartment, leading to a reduction in respiratory system compliance and increased airway pressures through elevation of the diaphragm [11]. It reduces pulmonary compliance and oxygen tension, while increasing PIP, mean airway pressure, carbon dioxide tension, intrapulmonary shunt, and pulmonary dead space [7]. Ppeak shows the pressure through the airways, from the mechanical ventilator as far as the alveoli, and represents the sum of the resistive, elastic, and positive end-expiratory pressures (PEEP). Pplateau generally represents alveolar pressure. The major problem during pneumoperitoneum is the decrease in functional residual capacity. Vascular compression, diaphragm elevation, and organ compression also contribute to the pathophysiology [12]. In the present study, patients with higher IAP also had higher Ppeak and Pplateau values than the lower IAP group after the start of pneumoperitoneum. In addition, the linear increment in these values was more prominent in the higher pressure group. Pneumoperitoneum also has an impact on $ETCO_2$ levels. Normally, adjustments are made to maintain $ETCO_2$ between 32 and 35 mmHg and to avoid hypercarbia. In this study however, even patients with higher IAP had $ETCO_2$ levels within normal limits. In one study involving morbidly obese patients undergoing either laparoscopic or open gastric bypass procedures, the laparoscopic procedure patients had higher $ETCO_2$, PIP, and lower respiratory compliance [13]. Similarly, higher $ETCO_2$ values were observed in patients with higher IAP levels in the present study. Linear increment was also more prominent in these patients. Umar et al. [14] showed that $ETCO_2$ increased immediately after insufflation and that the rise continued with the duration of CO_2 insufflation. Higher $ETCO_2$ values were also observed with higher IAP.

Increased IAP compresses the diaphragm, and intrathoracic pressure increases. When IAP values exceed 10 mmHg, hypovolemia occurs, cardiac output and venous return drop, systemic vascular resistance increases, and mean arterial blood pressure may initially rise due to shunting of blood away from the abdominal cavity, but normalizes or decreases thereafter [12]. In the present study, higher abdominal pressure had a more prominent effect on MAP at the end of pneumoperitoneum. Additionally, the increment in MAP during surgery was more marked in patients with higher IAP, while patients with lower IAP had higher HR values at all time intervals. Vivier et al. [15] reported in their animal study that HR and MAP were not affected by incremental increases in IAP, irrespective of volemia. Similarly, MAP did not change significantly during obesity surgery [9]. Umar et al. [14] compared the hemodynamic changes in patients undergoing laparoscopic cholecystectomy using different IAPs. They showed that mean HR and MAP increased during CO_2 insufflation and that the rise in HR persisted until exsufflation. Intergroup comparison showed that higher IAP resulted in higher MAP and HR values. One previous meta-analysis revealed that decompressive laparotomy caused a dramatic decrease in pressure in patients with high IAP, and resulted in a postoperative decrease in HR, an increase in MAP, and a decrease in PIP and PEEP [16].

Some limitations should be recognized while interpreting the study findings. This study included patients with hypertension which could interfere with increased ICP values. Also, surgical position, obesity, nasogastric suctioning, previous history of surgery, burns, pregnancy, peritoneal dialysis, and ascites can result in scarring of the abdominal wall or in adhesions, and can thus interfere with IAP [1]. However, these parameters were beyond the scope of this study. Nevertheless, the surgeon should create a sufficient laparoscopic work space, with the lowest possible pressure, without reaching maximum intra-abdominal capacity, in order to avoid short- and long-term complications.

Conclusion

In conclusion, pneumoperitoneum involves a risk of increased ICP. Lower IAP values are associated with lower ICP and may be related to lower complication rates. ONSD measurement is a suitable, reliable alternative when invasive ICP monitoring is not indicated or is unavailable.

Conflict of interest

The authors declare that they have no competing interest.

Financial Disclosure

All authors declare no financial support.

Ethical approval

Ethical approval was received from the Ethics Committee.

References

1. Ott DE. Abdominal Compliance and Laparoscopy: A Review. JSLS. 2019;23. e2018.00080.
2. Kim EJ, Koo B, Choi SH, et al. Ultrasonographic optic nerve sheath diameter for predicting elevated intracranial pressure during laparoscopic surgery: a systematic review and meta-analysis. Surg Endosc. 2018;32:175-82.
3. Sujata N, Tobin R, Tamhankar A, et al. A randomised trial to compare the increase in intracranial pressure as correlated with the optic nerve sheath diameter during propofol versus sevoflurane-maintained anesthesia in robot-assisted laparoscopic pelvic surgery. J Robot Surg. 2019;13:267-73.
4. Tayal VS, Neulander M, Norton HJ, et al. Emergency department sonographic measurement of optic nerve sheath diameter to detect findings of increased intracranial pressure in adult head injury patients. Ann Emerg Med. 2007;49:508-14.
5. Mehrpour M, Torshizi FO, Esmaeeli S. Optic nerve sonography in the diagnostic evaluation of pseudopapilledema and raised intracranial pressure: a cross-sectional study. Neurol Res Int. 2015;146059.
6. Amini A, Kariman H, Dolatabadi AA, et al. Use of the sonographic diameter of optic nerve sheath to estimate intracranial pressure. Am J Emerg Med. 2013;31:236-9.
7. Cheatham CL. Abdominal compartment syndrome: Pathophysiology and definitions. Scand J Trauma Resusc Emerg Med. 2009;17:10
8. Dip F, Nguyen D, Rosales A, et al. Impact of controlled intraabdominal pressure on the optic nerve sheath diameter during laparoscopic procedures. Surg Endosc. 2016;30:44-9.
9. Montorfano L, Giambartolomei G, Funes DR, et al. The Cushing reflex and the vasopressin-mediated hemodynamic response to increased intracranial pressure during acute elevations in intraabdominal pressure. Surgery. 2019;167:478-83.
10. Depauw PRAM, Groen RJM, Van Loon J, et al. The significance of intra-abdominal pressure in neurosurgery and neurological diseases: a narrative review and a conceptual proposal. Acta Neurochirurgica. 2019;161:855-64.
11. Wauters J, Claus P, Brosens N, et al. Relationship between abdominal pressure, pulmonary compliance, and cardiac preload in a porcine model. Crit Care Res Pract. 2012;2012:1-6.
12. Malbrain ML. Respiratory effects of increased intra-abdominal pressure. Réanimation. 2007;16:49-60.
13. Nguyen NT, Anderson JT, Budd M, et al. Effects of pneumoperitoneum on intraoperative pulmonary mechanics and gas exchange during laparoscopic gastric bypass. Surg Endosc. 2004;18:64-71.
14. Umar A, Mehta KS, Mehta N. Evaluation of Hemodynamic Changes Using Different Intra-Abdominal Pressures for Laparoscopic Cholecystectomy. Indian J Surg. 2013;75:284-9.
15. Vivier E, Metton O, Piriou V, et al. Br J Anaesth. 2006;96:701-7.
16. Van Damme L, De Waele JJ. Effect of decompressive laparotomy on organ function in patients with abdominal compartment syndrome: a systematic review and meanalysis. Crit Care. 2018;22:179.