ORIGINAL ARTICLE

The effect of different levels of elevated intraperitoneal pressure on the cerebral perfusion pressure during laparoscopic cholecystectomy

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ABSTRACT

Background: In spite of an ever increasing number of laparoscopic techniques, there is still a lot of arguments about multiple aspects of this technique as regards the best method for accessing the peritoneal cavity by creating pneumoperitoneum which may have many effects on cerebral perfusion state and oxygen consumption. We conducted this study to evaluate the effect of different levels of elevated artificial intraperitoneal pressure on the cerebral perfusion pressure (CPP) during laparoscopic cholecystectomy.

Methodology: This prospective, randomized clinical trial enrolled 40 patients scheduled for elective laparoscopic cholecystectomy, 20 - 59 years old, of either sex, and ASA I and II.

After ethical approval, patients were randomly assigned into two groups to receive, either: intraperitoneal pressure of 12 mmHg (Group PL) or a pressure of 20 mmHg (Group PH).

Results: No significant differences in heart rate, arterial oxygen saturation and end tidal Co_2 between both groups. Mean arterial pressure and CPP were lower in Group PH vs. Group PL at 2nd intraoperative reading. CPP at this point was lower in both groups compared to basal value, MAP in Group PH was lower and JBP was higher at 2nd intraoperative reading than basal value. PaO_2 and cerebral oxygen extraction ratio (COER) were lower in Group PH vs, Group PL, also PaO_2 was lower in Group PH compared to basal value at 2nd intraoperative reading.

Conclusions: During laparoscopic cholecystectomy, there is frequently reported alterations in cerebral blood flow and intracranial pressure. These changes affect cerebral perfusion pressure and thus may affect cerebral oxygenation.

Key words: Pneumoperitoneum; Intraperitoneal Pressure, Cerebral perfusion pressure, Cerebral oxygen extraction ratio; Laparoscopic cholecystectomy.

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INTRODUCTION

The use of laparoscopic surgical techniques is ever increasing in different surgical fields as it provides comparatively less traumatic and more cosmetic ways for surgical intervention. Yet still a lot of arguments are being offered for and against its use and about multiple uses of this technique.

One of the main issue is the optimal method of creating the pneumoperitoneum. No consensus exists as regards the best method for accessing the peritoneal cavity with regard to the establishment of pneumoperitoneum, the puncture with Veress needle represents the most popular technique.[1] Many complications in laparoscopy procedures occur at the start of the procedure, either during the introduction of the Veress needle or the first trocar[2]

In previous studies it has been proved that Veress needle and the first trocar may cause gastrointestinal injuries and vascular lesions in up to 0.04% and 0.02% respectively of procedures performed. The incidence of these complications is low, however, the consequences may be deadly[3]

Very high pressure caused by an artificial pneumoperitoneum can effectively protect the intra-abdominal structures against injury[4] when using the first trocar in the midline.[5]

High intra-peritoneal pressures provide some advantages, but a prolonged use can cause hemodynamic changes in the body, including decreased cardiac output and venous return, raised mean arterial pressure (MAP) and systemic vascular resistance and diversity in renal perfusion and glomerular filtration. In addition, ischemic lesions and reperfusion injury of intra-abdominal organs may occur.[7]

This study aimed at improve the safety of the introduction of the first trocar and investigate the changes in cerebral perfusion pressure (CPP) and cerebral oxygen extraction ratio (COER) caused by high intraperitoneal pressures (IPP) aiming to define the most appropriate pressure.

METHODOLOGY

For this prospective, randomized clinical trial, approval was obtained from the Research Ethics Committee of Mansoura University. The study was conducted at Mansoura University Hospital in Mansoura city, starting from December 2014 until January 2016. All patients, who were scheduled for elective laparoscopic surgery, between 20 and 59 years old, of either sex, classified into ASA I - II according to their physical condition, with no history of abdominal surgery on organs located at the abdominal supramesocolic level, without previously diagnosed peritonitis and with body mass index (BMI) less than 35, were included in the studied. Written informed consent was obtained.

Upon obtaining odd and even numbers on the upper face of a dice rolling, patients were randomly assigned to Group L: IPP of 12 mmHg; and Group H: IPP of 20 mmHg.

All patients were evaluated in pre-anesthetic clinic prior to the date of surgery. Before starting anesthesia, modified Allen test was performed. All patients were hydrated with Ringer Lactate solution after insertion of 18G IV cannula. The patients were monitored by standard monitoring: ECG, pulse oximetry, non-invasive blood pressure and capnometry.

General anesthesia was induced by fentanyl 1 μg/kg, rocuronium 0.6-0.9 mg/kg and propofol 2 mg/kg. Anesthesia was maintained with sevoflurane in a mixture of oxygen and compressed air. All patients were mechanically ventilated with volume controlled ventilation using Fabius GS Dräger anesthesia machine with Dixtal model DX 2010 monitors. Initial ventilation was achieved with a fraction of inspired oxygen of 60%, positive end expiratory pressure (PEEP) - 6 cmH_2O, tidal volume - 7 mL/kg, respiratory rate - 15 breaths per min and inspiration/expiration ratio - 1:2.

Radial artery in the non-dominant hand was catheterized. Pneumoperitoneum was achieved by closed technique with CO_2 insufflation at a rate of 1 L/min.

During the procedure, blood gas analysis was done. Also MAP, jugular bulb pressure (JBP), CPP, arterial O_2 content, jugular bulb O_2 content and COER were monitored and calculated.

For estimation, cerebral oxygenation state and COER were calculated using the following equations:

$CaO_2 = (SaO_2 \times Hb \times 1.39) + (0.0031 \times PaO_2)$

$CjvO_2 = (SjvO_2 \times Hb \times 1.39) + (0.0031 \times PjvO_2)$

$CajO_2 = (CaO_2 - CjvO_2)$

$COER = 100 \times CajO_2/CaO_2$ where CaO_2 and $CjvO_2$ are the arterial and jugular venous bulb oxygen contents.

These parameters were evaluated in both groups at time zero, before pneumoperitoneum at:

1- Basal reading.
2- 1st intraoperative reading, when IPP reaches 12 mmHg in both groups.
3- 2nd intraoperative reading, after 5 min with IPP = 12 mmHg in Group L and after 5 min with IPP = 20 mmHg in Group H.
4- 3rd intraoperative reading, after 10 min with IPP = 12 mmHg in Group L and with return of IPP from 20 to 12 mmHg in Group H.
5- 4th intraoperative reading, counted 10 min after return of IPP to 12 mmHg in both groups.

All patients were monitored during the anesthesia-surgical procedure for the following parameters: heart rate and rhythm, pulse oximetry, capnometry ($EtCO_2$) and MAP.

In post-anesthesia recovery room, heart rate and rhythm, MAP, pulse oximetry, were observed, until patients' discharge to the ward.

Parameter values, HR less than 75 b/min.; MAP 70 -120 mmHg; SaO_2 greater than 93%; $EtCO_2$ 30 to 45 mmHg; pH between 7.35 and 7.45, $PaCO_2$ 30 to 45 mmHg; PaO_2 above 80 mmHg; BE −2 to +2; and HCO_3 22 to 26 mEq/ L were considered normal.

Statistical analysis:

Based upon the data from our pilot study, CPP in Group L at 2nd intraoperative reading was 60 ± 9. An a priori power analysis showed that we needed to include 17 case in each group to detect 20% reduction in CPP at 2nd intraoperative reading with an alpha error of 0.05 and a power of 85%. We increased the number of cases by 15% in order to compensate for dropping out during recruitment.

Data obtained were statistically analyzed using SPSS software version 21. Data were first tested for normality by Klomogorov-Smirnov test. Normally distributed continuous data were analyzed by using student t-test. Non-normally distributed continuous and ordinal data were analyzed using Mann-Whitey U test. Categorical data were analyzed by Chi-square or Fisher's exact test as appropriate. The results were presented as mean ± SD, or number and % of patients as appropriate. A p-value < 0.05 was considered statistically significant.

RESULTS

Forty patients in two groups completed the study. No statistically significant differences were found between two groups as regard age, sex, weight, height, anesthesia and operation time (Table 1).

No statistically significant differences in heart rate, peripheral oxygen saturation and $EtCO_2$ when both groups were compared (Table 2).

MAP and CPP were lower in Group H in comparison to Group L at the second intraoperative reading. CPP at the second intraoperative reading was lower in both groups when compared to basal value similarly, MAP in Group H was lower than basal value and jugular pressure was higher at the second intraoperative reading (Table 3).

Arterial oxygen tension (PaO_2) and COER were lower in Group H when compared to Group L at the second intraoperative reading, also PaO_2 was lower in Group H when compared to the basal value at the second intraoperative reading (Table 4).

Table 1: Demographic data of the studied groups [data expressed as numbers or mean ± SD]

Variable	Group L (n=20)	Group H (n=20)	P value
Age (y)	37 ± 6	38 ± 5	0.774
Weight (Kg)	56 ± 12	57 ± 11	0.642
Height (cm)	153 ± 9	152 ± 7	0.981
Sex (M:F)	4 / 16	3 / 17	0.793
Anesthesia time (min)	66 ± 12	68 ± 11	0.607
Operation time (min)	53 ± 13	51 ± 12	0.365

DISCUSSION

It is well known that, almost all complications which take place during laparoscopic procedures often occur at the beginning of the procedure either by gas insufflation or by raising the intra-abdominal pressure. Consequently, this study was designed to compare two different levels of artificial pneumoperitoneum during laparoscopic cholycystectomy in order to achieve better hemodynamic stability, adequate cerebral perfusion together with reduction in perioperative untoward events.[8-10]

In this study, MAP and CPP were found to be lower in P20 group in comparison to P12 group at the

Table 2: Heart rate (b/min.), SpO_2 (%) and end tidal CO_2 (mmHg) of the studied groups, data are expressed as mean ± SD.

Time of reading	Heart rate		P value	End tidal CO_2		P value	SpO_2		P value
	Group L (n=20)	Group H (n=20)		Group L (n=20)	Group H (n=20)		Group L (n=20)	Group H (n=20)	
Basal	84 ± 12	86 ± 14	0.872	34 ± 3	35 ± 1	0.941	99 ± 2	99 ± 1	0.811
1st IO	75 ± 13	79 ± 11	0.971	35 ± 2	36 ± 2	0.455	99 ± 1	99 ± 2	0.547
2nd IO	76 ± 12	71 ± 15	0.932	31 ± 3	31 ± 1	0.876	99 ± 1	99 ± 1	0.623
3rd IO	74 ± 10	72 ± 13	0.824	**34 ± 2***	**29 ± 3***	0.821	99 ± 2	100 ± 1	0.471
4th IO	75 ± 11	79 ± 16	0.818	35 ± 4	35 ± 2	0.734	100 ± 1	99 ± 2	0.514
Basal ICU	86 ± 15	88 ± 13	0.792				**97 ± 2***	98 ± 1	0.371
1st ICU	82 ± 13	84 ± 12	0.621				98 ± 1	98 ± 2	0.486
2nd ICU	83 ± 14	80 ± 13	0.734				96 ± 2	**97 ± 1***	0.589

Table 3: Mean invasive arterial pressure (mmHg), jugular bulb pressure (mmHg) and cerebral perfusion pressure (mmHg) of the studied groups, data are expressed as mean ± SD.

Time of reading	MAP			CPP			JBP		
	Group L (n=20)	Group H (n=20)	P value	Group L (n=20)	Group H (n=20)	p value	Group L (n=20)	Group H (n=20)	p value
Basal	82 ± 9	81 ± 10	0.803	70 ± 11	71 ± 13	0.43	12 ± 3	10 ± 3	0.209
1st IO	76 ± 9	77 ± 8	0.063	62 ± 10	62 ± 10	0.46	14 ± 2	15 ± 1	0.211
2nd IO	75 ± 11	65 ± 9*	0.011	60 ± 9†	47 ± 9*†	0.79	15 ± 1	18 ± 2†	0.438
3rd IO	76 ± 13	75 ± 7	0.829	62 ± 9	62 ± 10	0.48	14 ± 2	13 ± 4	0.031
4th IO	79 ± 7	78 ± 9	0.570	69 ± 12	67 ± 11	0.22	10 ± 2	11 ± 4	0.51

$p < 0.05$ is considered significant when compared to P12 group. †$p < 0.05$ is considered significant when compared to the basal value.

Table 4: Arterial O_2 content or tension (PaO_2) and jugular bulb O_2 content or tension ($PJBO_2$), of the studied groups [data expressed as mean ± SD. 3rd or 2nd reading]

Time of reading	PaO_2			$PJBO_2$		
	Group L (n=20)	Group H (n=20)	p value	Group L (n=20)	Group H (n=20)	p value
1st IO	221 ± 16	219 ± 14	0.37	58 ± 9	59 ± 9	0.92
2nd IO	203 ± 12	205 ± 13	0.33	53 ± 8	51 ± 9	0.68
3rd IO	206 ± 11	193 ± 14*†	0.045	53 ± 10	52 ± 10	0.83
4th IO	211 ± 14	213 ± 15	0.52	61 ± 9	57 ± 8	0.69
Basal	224 ± 16	216 ± 17	0.49	60 ± 8	61 ± 10	0.87

$p < 0.05$ is considered significant when compared to P12 group.
†$p < 0.05$ is considered significant when compared to the basal value.

second intraoperative reading. In addition, CPP and MAP were lower in both group when compared to the basal value.[8]

In order to perform any laparoscopic procedures, CO_2 is insufflated into the peritoneal cavity. This artificial Pneumoperitoneum increases the intra-abdominal pressure, elevates the diaphragm and compresses both small and large blood vessels. The raised intra-abdominal pressure obtained during these procedures, which is usually around 12 mmHg increases central venous pressure (CVP), heart rate (HR), systemic vascular resistances (SVR) up by 65%, and the pulmonary vascular resistances (PVS) can rise up by 90%.[11-13]

In healthy patient, cardiac output (CO) can increase in Trendelenburg position, but can also decrease up to 50% on patients in anti-Trendelenburg position or with a low cardiovascular reserve.

All these changes are usually well tolerated in healthy patients but it can be different in patients with systemic diseases. Llagostera-Pujol et al, in 2002 explained that when the intra-abdominal pressure increases more than 15 mmHg, it can compress the cava vein, reducing the blood return which results in reduction of the CO. Similarly, the diaphragm elevation will raise the intra thoracic pressure

Table 5: Comparison of jugular venous oxygen saturation ($SJVO_2$) and cerebral oxygen extraction ratio (COER) (%) of the studied groups [data expressed as mean ± SD. 3rd or 2nd reading]

Time of reading	$SJVO_2$			COER		
	Group L (n=20)	Group H (n=20)	p value	Group L (n=20)	Group H (n=20)	p value
1st IO	74.5 ± 8	73.4 ± 9	0.12	26.87	28.2	0.072
2nd IO	70.4 ± 8	69.1 ± 7	0.92	35.86	32.65	0.481
3rd IO	71.3 ± 9.3	69.1 ± 8	0.54	34.19	27.04*	0.143
4th IO	71.2 ± 13	72.8 ± 10	0.13	31.68	30.20	0.365
Basal	71 ± 7.2	70.6 ± 9	0.93	30.89	30.40	0.821

*$p < 0.05$ is considered significant when compared to P12 group. *†$p < 0.05$ is considered significant when compared to the basal value.*

which will reduce the CO.[14] The lower CO can be compensated in a healthy patient by increasing the heart rate and arterial vasoconstriction, obtaining a stable hemodynamic status. Arrhythmia and bradycardia often appear in non atropinized patients during insufflation.[14]

However, it is not widely accepted that laparoscopy compromises hemodynamic and pulmonary functions. In one study, Basim and colleagues monitored non-invasively all cardiovascular parameters and pulmonary compliance during the initial entry using insufflation pressures up to 30 mmHg. Although they found minor changes in cardiovascular parameters, and all of them reverted to normal values once the pressure was decreased to 15 mmHg for the duration of the surgery. They found a gradual decrease in pulmonary compliance from the initial insertion of the Veress needle to a pressure of 15 mmHg and an additional 21% decrease from 15 to 30 mmHg. They concluded that although alterations in pulmonary compliance are statistically significant, they have no clinical significance and are tolerated well by healthy women. However, they recommended that all patients with compromised cardiopulmonary functions should not be exposed to such high pressures either during the initial entry to the abdomen or during the laparoscopic procedure itself. Such patients may be better served using alternative entry techniques or using lower IPPs.[15]

Another study conducted by Abu-Rafea and colleagues showed no cardiopulmonary complications in 100 healthy women undergoing high intra-abdominal pressure (between 10 and 30 mmHg) during the introduction of the first trocar. Although, the changes in MAP and pulmonary compliance were statistically significant, they were not clinically significant. However, they did not set parameters to assess changes in respiratory function and gas exchange. Moreover, the effect of each pressure level (10, 15, 20, 25 and 30 mmHg) was evaluated at the exact moment it was achieved, without taking into account the cumulative effect of the duration of pneumoperitoneum after insertion of the first trocar, and this makes difficult to assess the clinical effects resulting from the duration of pneumoperitoneum, rather than from the level of intra-abdominal pressure reached.[15]

The study by Fernando and colleagues aimed at evaluating whether intra-thoracic and abdominal pressure changes, in addition to oxygenation parameters, could cause an increase in intracranial pressure (ICP) values. The study showed that the correlation between CVP and ICP may suggest an increase in venous pressures caused by increased thoracic and abdominal pressures which have limited the cerebral venous drainage, subsequently increasing ICP.[16]

A study by Lee and colleagues observed the effect of gynecological laparoscopic surgery on cerebral oxygenation by changes in regional cerebral oxygen saturation (rSO_2). During the period of pneumoperitoneum, rSO_2 fell below 50% in two hypercapnic patients. In comparison with baseline, rSO_2 declined significantly in the Trendelenburg position. The creation of pneumoperitoneum itself did not decrease the average rSO_2 value further unless the patients were hypercapnic.[17]

Hypólitoa and colleagues in 2010 showed that the high intra-abdominal pressure is a safe practice, and no adverse clinical effects were observed by non-invasive monitoring analysis.[18] The results detected by Hypolitoa et al. in 2014, showed a statistically significant change was observed in MAP in both groups and throughout artificial pneumoperitoneum. The fact that this change was also observed in P12 group would suggest that its cause was due to the effect of pneumoperitoneum, even with a standard IPP. Even at low pressures (12 mmHg), a vasoconstriction reflex is triggered, with consequent increase in blood pressure. However, it is noteworthy that there was no case of hypertension in any of the groups. They reported that, the high (20 mmHg) and transient (5 min) intra-abdominal pressure for insertion of the first trocar causes changes in MAP, pH, HCO_3 and BE without clinical consequences for the patient and should be used to prevent the occurrence of iatrogenic injuries in the introduction of the first trocar.[19]

Also, jugular blood pressure (JBP) was higher at the second intraoperative reading in our study which is a result of increased intrathoracic pressure (ITP) and intra-abdominal pressure (IAP) that are known to influence ICP. However, the magnitude of this effect and its clinical relevance are unknown.

Several researches have highlighted the impact of intra-abdominal pressure on critical disease pathophysiology. The magnitude of pressure influence of thoracic and abdominal compartments with ICP in critical disease has been poorly studied. Intra-abdominal pressure can apparently affect ICP, likely because of increased venous and intra-thoracic pressures. Peritoneostomy has been described as a rescue therapy for refractory intracranial hypertension patients.

In our study, PaO_2 and COER were lower in P20 when compared to P12 group at the second intraoperative reading, also PaO_2 was lower in P20 when compared to the basal value at the second intraoperative reading.

This may be attributed to the fact that during laparoscopic surgery, there is frequently reported alterations in cerebral blood flow and ICP. These changes affect cerebral perfusion pressure and thus may affect cerebral oxygenation.

Measurement of the saturation of brain effluent blood gives a global estimate of cerebral oxygenation. It may provide clinicians with information to assist in reducing secondary insults to the brain with potential benefit studied by (Macmillan and Andrews 2000.[20]

CONCLUSION

The results of our study show that arterial oxygen tension and cerebral oxygen extraction ratio are lower when intraperitoneal pressure is set at 20 mmHg compared to 12 mmHg. These changes affect cerebral perfusion pressure and thus may affect cerebral oxygenation. Measurement of the saturation of brain effluent blood gives a global estimate of cerebral oxygenation and it may be useful in reducing secondary insults to the brain.

Conflict of interest: None declared by the authors

Authors' contribution:

HIT: Concept, conduct of study, statistical analysis, editing

DGD: Concept, conduct of study, literature search, editing

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