Original Article

The effect of different pressures of pneumoperitoneum on the dimensions of internal jugular vein - A prospective double-blind, randomised study

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ABSTRACT

Background and Aims: During laparoscopic surgeries, pneumoperitoneum increases intraabdominal pressure (IAP) which can increase the central venous pressure (CVP), and significant haemodynamic changes. In this study, we evaluated the effect of two different pressures of pneumoperitoneum, standard (13-15 mmHg), and low (6-8 mmHg) on the cross-sectional area (CSA) of the internal jugular vein (IJV) using ultrasonography, haemodynamic changes and duration of surgery. Surgeon's comfort and feasibility of performing laparoscopic surgeries with low pressure pneumoperitoneum was also studied. **Methods:** This prospective, double-blind, randomised study included 148 patients of American Society of Anesthesiologists physical status class I and II undergoing laparoscopic surgeries. They were allocated into two groups: group S (standard) (number (n) = 73) had the IAP maintained between 13-15 mmHg; group L (low) had an IAP of 6-8 mmHg (n = 75). CSA of right IJV was measured before induction of anaesthesia (T1), 5 min after intubation (T2), 5 min after pneumoperitoneum (T3), before desufflation (T4) and 5 min prior to extubation (T5). Chi-square test, and Student's paired and unpaired t test were used for statistical analysis. **Results:** The increase in IJV CSA at T3 when compared to T2 was statistically significant in both the groups ($P < 0.001$). On desufflation, the change in IJV CSA showed significant decrease in T5 value than T4 value in both the groups ($P < 0.001$). However, the percentage change in the IJV CSA was more in group S (35.4%) than group L (21.2%). **Conclusion:** CSA of IJV increased significantly even with lower IAP of 6-8 mmHg. Laparoscopic surgery can be performed conveniently even at low IAP.

Key words: Central venous pressure, laparoscopy, pneumoperitoneum, ultrasonography

INTRODUCTION

The technique of laparoscopy, being minimally invasive, is increasingly used for performing a variety of intra-abdominal surgeries like cholecystectomy, appendectomy, colectomy, Roux-en-Y gastric bypass, sleeve gastrectomy, and hysterectomy among others.[1] It involves gas insufflation into the peritoneal cavity producing pneumoperitoneum which increases intra-abdominal pressure (IAP) to 13-15 mm of Hg (standard pneumoperitoneum). Laparoscopy can also be done with lower IAP of 6-10 mmHg (low pressure pneumoperitoneum), which is technically challenging for the surgeons.[2] However, laparoscopy is not completely risk-free, producing significant

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haemodynamic changes, especially in elderly and haemodynamically compromised patients.[3] Increased IAP has a biphasic effect on venous return. Initially, due to auto-transfusion of pooled blood from the splanchnic circulation, there is a rise in the circulating blood volume, leading to a rise in venous return and flow. Further increase in the IAP causes inferior vena caval compression and decreases venous return with a subsequent decrease in cardiac output.[4] Use of lower IAP has shown better patient haemodynamics and lesser postoperative pain. There are studies that have explored various factors affecting the cross-sectional area (CSA) of central venous structures like the internal jugular vein (IJV). It has been reported that positive end-expiratory pressure (PEEP), positive pressure ventilation, Trendelenburg position, manoeuvres like Valsalva and hepatic compression increase the CSA of IJV.[5] During laparoscopic surgeries, CSA of IJV may increase due to increased IAP by carbon dioxide (CO_2) insufflation. Though there are reports on central venous pressure (CVP) increase,[6] very few studies to date have performed IJV-CSA measurements during pneumoperitoneum for laparoscopic cholecystectomy, and none of them compared measurements during low and standard pressure pneumoperitoneum. Our study aimed to investigate and quantify the change in IJV CSA using ultrasonography, and haemodynamic parameters elicited by pneumoperitoneum of different pressures (standard IAP versus low IAP) during laparoscopic surgeries.

METHODS

This prospective, randomised, double-blind study was carried out from May 2020 to April 2021, at a tertiary care institute after approval from the Institutional Ethics Committee and was registered at Clinical Trials Registry-India (CTRI/2020/05/024971, dated 01/05/2020). One hundred and forty eight American Society of Anesthesiologists (ASA) physical status grades I and II patients, aged between 18 and 50 years, of both genders, posted for laparoscopic surgery were included in the study. Written informed consent was obtained from all participants during pre-anaesthetic check and the study was done in accordance with the institutional ethics committee's standards on human experimentation and the Helsinki Declaration of 1975. Patients with uncontrolled hypertension, poorly controlled diabetes, cardiovascular diseases, severe chronic obstructive pulmonary diseases, chest wall deformities, pregnant and lactating women were excluded. Those with intraoperative conversion from low to standard IAP or to open laparotomy were considered as drop-outs.

Patients were randomly allocated into two groups by computer generated randomisation. Group S (standard) (number (n) = 73) had the IAP maintained between 13-15 mmHg and group L (low) had an IAP of 6-8 mmHg (n = 75) [Figure 1]. Three patients of group S (converted to open) and 5 patients of group L (intraoperatively converted to IAP of 14 mmHg) were excluded from the analysis. The final number of participants studied was 70 in each group. The participants were unaware of the allocated group. After pre-anaesthetic evaluation on the night before surgery, patients were kept fasting as per ASA guidelines. All patients were administered oral alprazolam 0.5 mg and ranitidine 150 mg, the night before surgery. On the day of surgery, the patients were brought into the operation theatre and an intravenous cannula was secured. Minimum mandatory monitoring was done with electrocardiogram, heart rate (HR), pulse oximeter, non-invasive blood pressure (NIBP), end-tidal CO_2 ($EtCO_2$). All the patients were administered general anaesthesia with propofol 2 mg/kg, intravenously (IV), sevoflurane at 0.5 to 1 minimum alveolar concentration (MAC), fentanyl

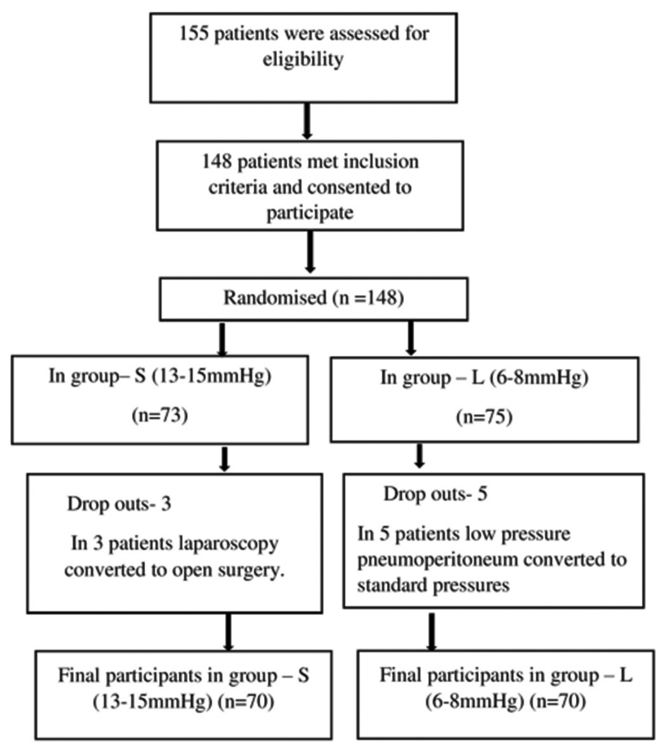

Figure 1: Consolidated Standards of Reporting Trials (CONSORT) flow diagram

l-2 μg/kg IV, vecuronium 0.1 mg/kg IV and endotracheal intubation was done. Anaesthesia was maintained by sevoflurane (1.8-2 volume %) using a fresh gas flow of 2 l/min. All the patients were ventilated with a tidal volume of 6-7 ml/kg body weight, respiratory rate of 12-14 breaths per minute and positive end-expiratory pressure of 4 cm of water using oxygen/air mixture at 40/60%. For all patients, pneumoperitoneum was initiated with CO_2 insufflation. Respiratory rate was adjusted to maintain an $ETCO_2$ level of 35-40 mmHg. HR, NIBP, $ETCO_2$ were recorded at set time points as mentioned below. The ultrasonographic measurement of cross-sectional area (CSA) of IJV was performed by a single-trained anaesthesiologist who was blinded to group allocation and was not involved in the study. The right IJV (for uniformity) was visualised with a 6-13 megahertz (MHz) two-dimensional linear ultrasonography transducer (FUJIFILM Sonosite Edge II, HFL38xi transducer) at the cricoid cartilage level. The measurements were taken at a depth of 4 cm in all patients and to obtain the optimal images, gain was adjusted. To avoid compression of the vein, minimum pressure was applied on the probe. On obtaining the best image, it was saved and the measurements of the vein such as the diameter and CSA were recorded. Using the cursor, the outline of the IJV image traced and the circumference (in cm) and CSA (in cm^2) were measured and noted at the end of expiration in supine position. Measurements were recorded at five different time points in the supine position: before the induction of anaesthesia (control T1), 5 min after intubation (T2), 5 min after creation of pneumoperitoneum (T3), 5 min after completion of surgery before desufflation (T4), and 5 min before extubation (T5) [Figure 2]. The duration of surgery was recorded. Pinar HU *et al*,[7] in their study observed a 20% increase in IJV CSA as significant. We considered a 30% increase in CSA of IJV as significant and with a standard deviation of 0.622, to achieve a confidence level of 95% and power of 80% had to enrol 68 patients in each group. Ultimately, we enroled a total of 148 patients in the two groups to account for any drop-outs.

The sample size was calculated using the formula:

$$N = \frac{2(Z_{\alpha} + Z_{1-\beta})^2 \times \sigma^2}{\Delta^2}$$

with Δ (effect size) = 0.3

The results were tabulated and statistically analysed using (Statistical Package for Social Sciences) Software version 21. Chi-square test, paired and unpaired t test were used for data analysis. A P value of <0.05 was considered as significant and <0.001 as highly significant. Surgeon comfort and feasibility with low IAP pneumoperitoneum was assessed using the Likert 5 point scale – 5 = very good, 4 = good, 3 = satisfactory, 2 = bad, 1 = very bad.

RESULTS

Both the groups were comparable with respect to age, gender, ASA physical status grade and duration of surgery [Table 1].

In group S, the CSA of IJV increased from a mean value of 1.13 cm^2 at T2 to 1.53 cm^2 at T3 and 1.55 cm^2 at T4. There was a 35.4% increase in the CSA from after intubation (T2) to creation of pneumoperitoneum (T3) which sustained till desufflation (T4). After desufflation, though the CSA decreased (1.55 cm^2 at T4 to 1.09 cm^2 at T5), it did not reach the baseline values. The *P* values were highly significant ($P < 0.001$) between T2 and T3 and T4 and T5 [Table 2].

In group L, the CSA of IJV increased from a mean value of 1.13 cm^2 at T2 to 1.37 cm^2 at T3 and

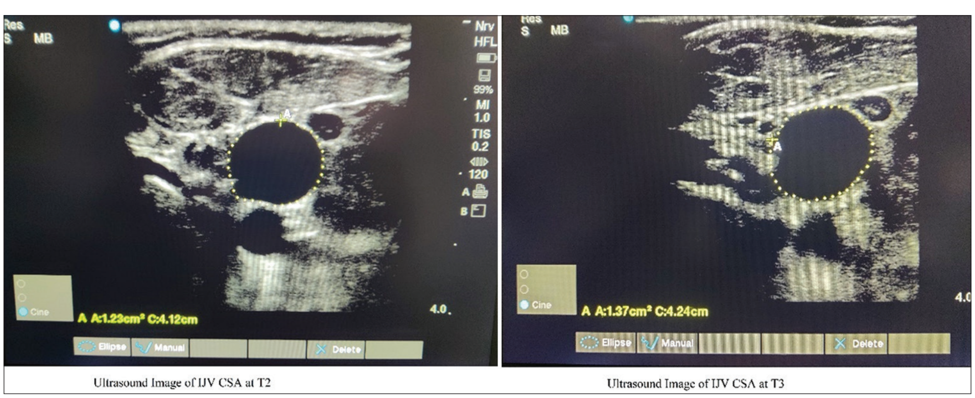

Figure 2: Internal jugular vein (IJV) cross-sectional area (cm^2) at time points T2 and T3 in the supine position

1.29 cm² at T4. There was a 21.2% increase in the CSA from after intubation (T2) to creation of pneumoperitoneum (T3) which sustained till desufflation (T4). After desufflation, the CSA decreased (1.29 cm² at T4 to 1.05 cm² at T5) but did not reach the baseline values. The *P* values were highly significant ($P < 0.001$) between T2 and T3 and in between T4 and T5 [Table 2].

On comparing group S and L at the different time intervals, the baseline values of CSA of IJV (T1) and values after intubation (T2) were comparable between the two groups. T1–CSA was taken as baseline (control) before intubation. We compared between T2–T3 and T4–T5 and hence the percentage change in CSA of IJV at T3, T4 and T5 could be attributed to the increase in IAP due to pneumoperitoneum [Figure 3]. In both groups, the HR, systolic blood pressure (SBP) and diastolic blood pressure (DBP) were comparable to each other and there was no statistical difference between them [Figure 4].

Overall surgeon comfort and feasibility with standard IAP pneumoperitoneum was "very good" and three of five surgeons expressed their experience as "good" and two surgeons as "satisfactory" with low IAP pneumoperitoneum. The comfort level may further improve on using low IAP pneumoperitoneum for all feasible laparoscopic surgeries.

DISCUSSION

Laparoscopic surgery accounts for more than two million surgical procedures every year. During laparoscopic surgeries, pneumoperitoneum is created by insufflating CO_2 gas to improve the visibility and mobility in the surgical field. Nevertheless, the pneumoperitoneum modifies the homeostasis of the abdominal cavity and might promote metabolic changes through mechanical and biochemical

Table 1: Demographic data

Variable	Group S (13-15 mm Hg)	Group L (6-8 mm Hg)	Total *n* (%)
ASA grade 1 *n* (%)	42 (60)	36 (51.4)	78 (55.7)
ASA grade 2 *n* (%)	28 (40)	34 (48.6)	62 (44.3)
Gender male/female *n* (%)	14/56	28/42	
Age (years) mean±SD	32.77±7.78	38.4±12.67	
Duration of surgery (minutes) mean±SD	88.77±31.02	89.62±26.7	

ASA=American Society of Anesthesiologists, SD=standard deviation, *n*=number

Table 2: Comparison of IJV CSA at time points T2 and T3, T4 and T5

Variable	T2 Mean±SD	T3 Mean±SD	*P*
IJV CSA (group S) (cm²)	1.12±0.41	1.52±0.55	<0.001
IJV CSA (group L) (cm²)	1.128±0.438	1.365±0.497	<0.001
Variable	**T4 Mean±SD**	**T5 Mean±SD**	***P***
IJV CSA (group S) (cm²)	1.545±0.520	1.087±0.329	<0.001
IJV CSA (group L) (cm²)	1.295±0.452	1.067±0.375	<0.001

IJV=internal jugular vein, CSA=cross-sectional area, SD=standard deviation

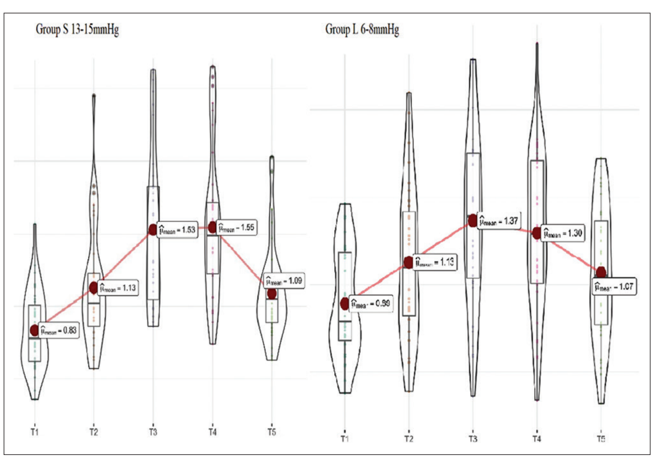

Figure 3: Comparison of internal jugular vein (IJV) cross-sectional area (CSA) cm² at different time points between group S (standard IAP) and L (low IAP)

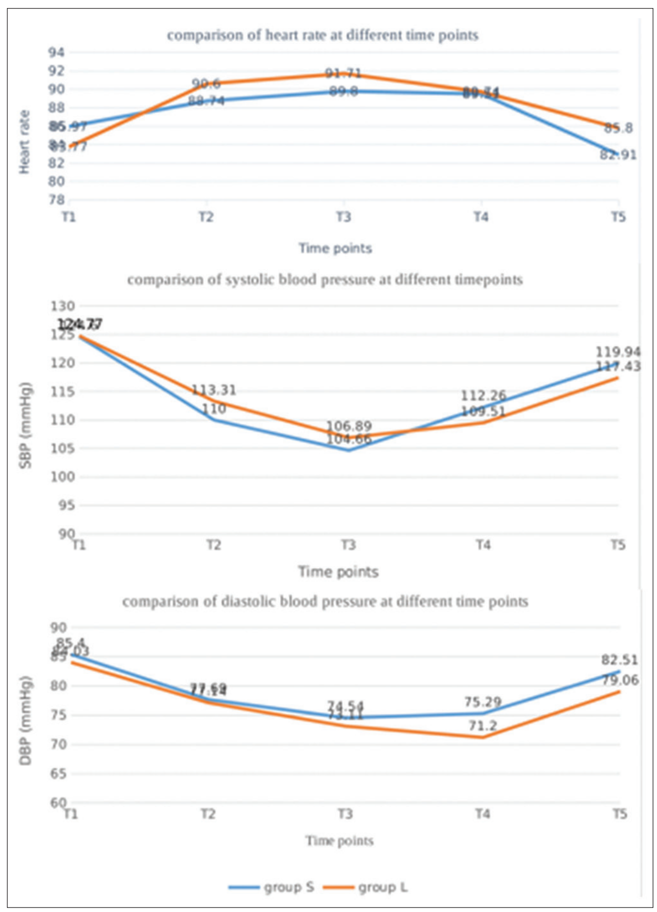

Figure 4: Comparison of haemodynamic parameters at different time points between groups S and L. SBP: Systolic blood pressure; DBP: Diastolic blood pressure

effects.[8] Traditionally, pneumoperitoneum is set at the standard IAP of 12-14 mm Hg.[9] Bearing in mind the potential impact of pneumoperitoneum on cardiopulmonary function and postoperative pain,[10] international guidelines recommend that the use of "the lowest IAP allowing adequate exposure of the operative field rather than a routine pressure" should be used.[11] In literature, low-pressure pneumoperitoneum is generally defined as an IAP of 6–10 mmHg.[2]

CO_2 insufflation during pneumoperitoneum may produce significant haemodynamic and ventilatory consequences.[4,12] Increased IAP results in haemodynamic changes like increase in the preload and afterload in the beginning followed by a fall in the cardiac output. The ventilatory consequences of pneumoperitoneum are an increase in intrathoracic pressure and peak airway pressures, reduced pulmonary compliance and hypercarbia.[13] These haemodynamic changes intensify in patients with cardiovascular disease like congenital heart disease, valvular heart disease, pulmonary hypertension, ischaemic heart disease and congestive heart failure.[14] CO_2 insufflation, impacts the cardiovascular, respiratory and renal systems, secondary to mechanical and neurohormonal responses to increased IAP and hypercarbia. All these changes may affect patients, especially those with altered intracranial compliance. In a study, trans-oesophageal echocardiography has demonstrated that there was significant increase in left ventricular preload (end diastolic diameter of left ventricle), afterload (end systolic wall stress of left ventricle) and a decrease in cardiac function (fractional area shortening) within 3 min of insufflation of the abdomen. However, in healthy individuals, though these changes can reach the baseline after 30 min of insufflations, they may produce deleterious effects in individuals with cardiovascular insufficiency.[15] In the current study, we looked at the effects of two different pressures of pneumoperitoneum on the IJV CSA. Based on the results of the study, pneumoperitoneum of IAP 13-15 mmHg caused significant increases in CSA of IJV and on desufflation, IJV CSA decreased significantly. The value of IJV CSA after desufflation (T5) was higher than basal measurements. This might be due to mechanical ventilation leading to an elevated intrathoracic pressure. Although we had hypothesised that low pressure pneumoperitoneum will not produce much changes in the CSA- IJV, still the changes in CSA-IJV taken at time points T2-T4 were highly significant, emphasising the fact that pneumoperitoneum of any magnitude causes significant cardiac changes. Though the change in mean CSA of IJV was statistically significant in both the groups (P value < 0.001), the percentage change (increase) of IJV-CSA from T2 to T3 in group L (lower IAP) was lesser compared to group S (standard IAP) (21.2% and 35.4% respectively).

Previous studies have reported variable haemodynamic effects due to different pressures of pneumoperitoneum.[16] In a study by Dexter *et al*.,[17] subjects posted for laparoscopic cholecystectomy were allocated into two groups (IAP of 7 mmHg and 15 mmHg). Though there was an increase in HR and mean arterial pressure (MAP) in the two groups, the authors found a decrease in stroke volume and cardiac output in the 15 mmHg group by 10 and 26%, respectively.[7] McLaughlin *et al*.,[18] in their study reported that with a pneumoperitoneum of 15 mmHg, there was a 60% increase in MAP and a 30% fall in stroke volume and cardiac output.[7] Another study reported an increase in venous return with an IAP less than 15 mmHg due to squeezing of the venous bed and a fall in venous return and blood pressure due to compression of the inferior vena cava with an IAP of 15 mmHg or more.[19] In our study, there were no significant changes in the HR, SBP and DBP between the groups. This may be due to appropriate titration of the respiratory rate and $ETCO_2$ levels to avoid hypercarbia and adjusting the depth of anaesthesia to maintain stable haemodynamics. Pinar HU *et al*., found an increase in CSA of IJV and SCV with pneumoperitoneum of 12 mmHg at both expiration and inspiration, which decreased to prior values on desufflation.[7] This was similar to the findings of the current study, however, different pressures of pneumoperitoneum were not used in their study. Low pressure pneumoperitoneum decreases postoperative pain, analgesic consumption and seems to improve perioperative functioning of the liver and kidney. There is also a tendency towards a shorter hospital stay.[20]

Cyprian Ogum *et al*.,[21] measured right IJV CSA and circumference using ultrasound. Later, a central line was secured and the CVP was measured. They found a significant correlation between IJV CSA and conventional catheter-based CVP readings. In our study, we planned to investigate the effect of standard (13-15 mmHg) and low (6-8 mmHg) pressure pneumoperitoneum on IJV CSA and CVP measurement was not done. Further studies are required to determine whether the correlation between

IJV CSA and CVP exists during different pressures of pneumoperitoneum. The limitations of our study are that the study was performed in ASA physical status I and II patients and the measurements were taken in supine position in surgeries of duration not exceeding 2 hours and there were no significant changes noted in the haemodynamic parameters.

Moreover, a larger sample size will be required to look for any qualitative differences between high and low pressure groups. CVP was not measured as it is unethical to perform central venous cannulation in all patients undergoing laparoscopic surgeries. Imaging with USG is very subjective and operator dependant and if done with different operators, it can introduce bias in the study.

CONCLUSION

The percentage change in the CSA of IJV was more in the high pressure pneumoperitoneum group (35.4%) when compared to the low pressure group (21.2%) implying that pneumoperitoneum of any magnitude can cause a significant increase in CSA of the IJV which may have a clinical impact in susceptible individuals. Laparoscopic surgery can be performed conveniently at low IAPs of 6–8 mmHg.

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Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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