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A Comparison of Pressure-Controlled and Volume-Controlled Ventilation for Laparoscopic Cholecystectomy

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ABSTRACT

The potential advantages of pressure-controlled versus volume-controlled ventilation during laparoscopic surgery have not yet been established yet in the previous literature. In this regard, 42 patients with a BMI of 30 kg.m2 who were scheduled to undergo laparoscopic cholecystectomy were randomly assigned to pressure- or volume-controlled ventilation. Compared to volume-controlled ventilation, pressure-controlled ventilation resulted in a significant decrease in peak airway pressure at 10 and 30 minutes (p = 0.003 and 0.014, respectively) and an increase in mean airway pressure at 10 minutes (10.50 (0.8) vs 9.61 (1.2) cmH2O). Similarly, there occurred gas exchange and hemodynamic stability. For non-obese people undergoing laparoscopic cholecystectomy, we conclude that pressure-controlled ventilation is a safe alternative to volume-controlled ventilation.

INTRODUCTION

Laparoscopic cholecystectomy has almost entirely replaced open cholecystectomy; nonetheless, pneumoperitoneum and the resulting increase in intra-abdominal pressure are related with an increase in peak airway pressure. Volume-controlled (VC) ventilation is the most common method for intra-operative use; nevertheless, rising peak airway pressure usually demands changes to the set tidal volume and respiratory rate to maintain efficacy. In spite of the fact that pressure-controlled (PC) ventilation may offer more control over airway pressure due to its decelerating inspiratory flow pattern [1], it is a rather uncommon ventilation technique in the operating room. Moreover, PC ventilation may be associated with an increase in mean airway pressure [2-4], which may improve oxygenation [2, 5, 6].

Several studies [5, 7] have investigated the utility of PC ventilation in obese patients undergoing laparoscopic bariatric surgery. However, the outcomes for non-obese persons are inconsistent [2, 8]. To determine the impact of the two ventilation techniques on pulmonary mechanics and gas exchange in non-obese individuals undergoing laparoscopic cholecystectomy, we decided to conduct a randomised controlled trial. We chose to test the null hypothesis that ventilation mode has no effect on mean airway pressure; this was chosen as the primary outcome measure not only because it represents the average of airway pressure throughout the entire respiratory cycle, but also because it is directly related to gas distribution and exchange in alveoli with non-homogeneous time constants [1].

METHODOLOGY

The trial was approved by the Ethical Review Board of Khyber teaching Hospital . Patients between the ages of 18 and 65 who were scheduled for laparoscopic cholecystectomy under general anaesthesia and provided written informed consent were enrolled in the study. Exclusion criteria included intraoperative use of an airway device other than a tracheal tube, a history of respiratory disease, and the requirement for postoperative mechanical ventilation.

Using pre-sealed, opaque envelopes created by a neutral observer and picked at random, patients were assigned to one of two groups (VC or PC ventilation). The ventilation settings for both groups were chosen by a custom-designed algorithm. In both groups, the starting tidal volume was set at 8 ml/kg1. In the PC group, the ventilator was set up to deliver the necessary tidal volume at the predefined pressure (a variation of 5 percent was accepted). In all groups, the ratio of inspiratory to expiratory time was 1:1, the percentage of inspired oxygen (FIo2) was 0.3%, and a PEEP of 5 cmH2O was administered. The algorithm accepted fluctuations in respiratory rate and tidal volume in order to maintain normocapnia (end-tidal carbon dioxide between 4.7 and 5.3 kPa). To maintain a Spo2 greater than 97%, the FIo2 was increased from 0.3 as necessary.

All patients were monitored continuously with ECG, pulse oximetry, capnography, and spirometry (S5 monitor – Datex Ohmeda; GE Healthcare, Waukesha, WI, USA), and invasive arterial pressure measurements were taken through the radial artery. Continuously displaying the cardiac index, a FloTracTM sensor and VigileoTM monitor were linked to the arterial line to display the cardiac index (Edwards Lifesciences, Irvine, California, United States). 10 ml.kg1.h1 Intravenous Hartmann's solution was administered. Following the administration of 2 g.kg1 fentanyl and 1.0–2.5 mg.kg1 propofol to induce anaesthesia, the trachea was intubated with 0.1 mg.kg1 vecuronium. In addition to 1 MAC of isoflurane, oxygen and nitrous oxide were administered to maintain anaesthesia. As clinically indicated, the anesthesiologist administered more medications and fluids while maintaining the patient's heart rate and blood pressure within 20% of their baseline values. The abdominal cavity of supine patients was insufflated with CO2 to a maximum intra-abdominal pressure of 12 mmHg during surgery. The patient's head was then elevated by 15 to 20 degrees for the duration of treatment. Neostigmine 0.05 mg.kg-1 and atropine 0.02 mg.kg-1 were administered postoperatively with 8 mg of ondansetron. After tracheal extubation and facemask administration of oxygen (FIo2 0.3), patients were brought to the recovery room, where any cases of Spo2 95 percent within the first two hours were documented.

Intraoperative data were collected at three time points: five minutes after tracheal intubation, ten minutes after laparoscopy commencement, and thirty minutes after laparoscopy initiation. Also documented was the total amount of CO2 absorbed during insufflation. Using version 26 of SPSS, data analysis was performed. To compare repeated measures, the general linear model of analysis of variance (ANOVA) with the Tukey test and Bonferroni correction was utilised. Use Fisher's exact test or the chi-squared test to compare qualitative data. Based on previously published data demonstrating mean (SD) airway pressures of 7 (2) and 9 (2) cmH2O with VC and PC ventilation, respectively [2], we concluded that 21 patients per group were necessary to reach 90% power and a significance level of 0.05.

RESULTS

The characteristics and baseline data of the two groups (each consisting of 21 patients) were identical, as were the total volume of carbon dioxide insufflated, the duration of surgery, and intra-operative fluid administration (Table 1).

Five minutes after tracheal intubation, the peak and mean airway pressures in the VC and PC groups were identical. However, 10 and 30 minutes after the beginning of operation, peak airway pressure was considerably lower and mean airway pressure was significantly higher in the PC group than in the VC group (Table 2). We also noticed that compliance was much greater in the PC group, but just five minutes after tracheal intubation; there was no difference after the surgery began.

Blood gases and end-tidal CO2 did not differ between the two groups (Table 3), except for arterial pH, which was larger in the PC group 30 minutes after surgery began (Table 2). Within two hours of the conclusion of the procedure, there were no instances of arterial oxygen desaturation (Spo2 95%) and no changes in hemodynamic data (Table 3).

Table 1: Baseline and intraoperative data for laparoscopic cholecystectomy patients. Mean (SD) or number (%) values are provided.

	VC (n=21)	**PC (n=21)**
Age in years	34 (11)	35 (12)
Gender (Females)	20 (95%)	20 (95%)
Height in centimeters	156 (6)	157 (8)
Weight in kilograms	58 (9)	56 (10)
BMI in kg.m^{-2}	24 (4)	23 (3)
Heart rate in beats.min^{-1}	94 (17)	93 (15)
Mean arterial pressure in mmHg	101 (9)	99 (10)
Cardiac index in l.min^{-1}.m^{-2}	4.5 (0.9)	4.4 (1.2)
S_pO_2 in percentage	99 (1)	99 (1)
Volume of CO_2 insufflated in liters	78 (36)	68 (26)
Duration of laparoscopy in minutes	61 (21)	52 (23)
Intravenous fluid in ml	1252 (260)	1202 (212)

Table 2: Respiratory data and blood gas measurements for patients undergoing laparoscopic cholecystectomy at three time points: T1, 5 minutes after tracheal intubation, T2, 10 minutes, and T3, 30 minutes; values are mean (SD); p value is for overall intergroup comparison.

	VC			**PC**			
	T1	**T2**	**T3**	**T1**	**T2**	**T3**	**p Value**
P(peak)	18.6 (3.5)	23 (4.6)	23.8 (4.8)	15.5 (3.1)	20.3 (2.6)	20.6 (3.1)	0.003
P (mean)	8.6 (0.7)	9.5 (1.2)	9.5 (1.1)	8 (1.0)	10.4 (0.8)	10.4 (1.2)	0.009
C (dyn)	37 (11)	22 (4)	24 (4)	43 (10)	27 (6)	28 (6)	0.019
Resistance	11 (3)	11 (4)	13 (5)	11 (4)	13 (5)	13 (3)	0.078

Tidal volume (ml)	468 (68)	416 (66)	436 (68)	451 (70)	411 (65)	430 (60)	0.414
Respiratory rate	11 (2)	12 (1)	11 (1)	11 (2)	12 (2)	12 (2)	0.450
Minute ventilation	5.3 (0.7)	5.1 (1.3)	5.2 (1.0)	4.7 (0.6)	4.4 (0.7)	4.5 (0.6)	0.028
P_aO_2	21 (4.7)	17.2 (3.1)	17.4 (5)	23.2 (5.6)	19.2 (4.2)	18.8 (4.3)	0.186
P_aO_2/F_iO_2	521 (96)	421 (83)	435 (101)	579 (146)	471 (108)	472 (118)	0.171
P_ECO_2	4.3 (0.4)	5.1 (0.2)	5.1 (0.2)	4.4 (0.3)	5.1 (0.2)	5.1 (0.2)	0.240
P_aCO_2	4.2 (0.7)	4.8 (0.7)	5.1 (0.7)	4.1 (0.6)	4.8 (0.6)	4.6 (0.8)	0.145
pH	7.42 (0.03)	7.33 (0.05)	7.32 (0.06)	7.43 (0.04)	7.36 (0.04)	7.38 (0.04)	0.013

Table 3: T1, 5 minutes after tracheal intubation; T2, 10 minutes; and T3, 30 minutes following the initiation of surgery. Values are mean (SD).

	VC			**PC**			
	T1	**T2**	**T3**	**T1**	**T2**	**T3**	**p Value**
Heart rate	88 (13)	78 (12)	81 (12)	85 (11)	82 (13)	81 (12)	0.834
Mean arterial pressure	86 (13)	96 (16)	91 (12)	83 (11)	101 (14)	98 (11)	0.718
Cardiac index	3.2 (0.6)	3.5 (0.7)	3.3 (0.4)	3.1 (0.4)	3.7 (0.6)	3.6 (0.7)	0.385

DISCUSSION

The alterations are equivalent to those documented in prior laparoscopic non-bariatric surgical investigations. Nonetheless, this was not accompanied by an improvement in gas exchange. [2, 8]. PC ventilation has been shown to reduce peak airway pressure in several conditions, including severe lung injury/acute respiratory distress syndrome [9-11], under one-lung anaesthesia [12, 13], and in morbidly obese patients [14]. Furthermore, similar variations in ventilation were not detected in other studies of obese individuals [5, 7]. This may be owing to the physiological respiratory system difficulties associated with obesity, which may affect mechanical ventilation irrespective of laparoscopy-induced dysfunction [15].

Several types of ventilatory strategies have been evaluated to establish their impact on laparoscopic surgical conditions. Williams et al. compared the effects of mechanical breathing to spontaneous ventilation during laparoscopic gynaecological surgery [16]. Mechanical ventilation was associated with significantly increased pneumoperitoneum (facilitating surgical access) and decreased intra-abdominal pressure.

The reduction in peak airway pressure associated with PC ventilation is likely attributable to its decelerating inspiratory flow pattern [9, 17], with the greatest value occurring early in inspiration. This is followed by a decrease in flow rate, resulting in the unique form of the water. PC ventilation may be associated with an increase in mean airway pressure [4] because to the early alveolar expansion caused by initial fast flow. The mean airway pressure is related to the mean alveolar pressure and may directly improve oxygenation [2-4, 6]. There is evidence that PC ventilation enhances oxygenation in patients with respiratory failure [18, 12], during one-lung anaesthesia [12], and in obese patients having laparoscopy [5]. According to the results of our experiment, there was no statistically significant change in gas exchange. Given that the primary endpoint was mean airway pressure and that the study lacked the ability to identify changes in oxygenation, this may be a result of insufficient power. In addition, despite being statistically significant, the minute change in mean airway pressure may not have had a discernable effect on gas exchange.

In this study, there were no statistically significant differences between PC and VC ventilation in carbon dioxide removal markers, such as minute ventilation demand and Paco2. Probably as a result of algorithm-driven alterations to the ventilator's settings throughout the procedure. The minute ventilation demand was statistically comparable for the two ventilation methods, although the study was underpowered to establish this conclusion.

In contrast to the improved compliance observed in past trials [2, 8] with PC breathing, pneumoperitoneum was not linked with any significant compliance changes. Our findings pertain to laparoscopic upper abdominal surgery conducted in the reverse Trendelenburg position, while Balick-Weber et al. [2] and Ogurlu et al. [8] examined patients undergoing laparoscopic urological or gynaecological surgery in the Trendelenburg position, respectively. In comparison to the reverse Trendelenburg position, the Trendelenburg position improves lung resistance and flexibility [19]. We were unable to find any studies that assessed the effect of PC ventilation in various patient positions; therefore, it is unknown if the compliance advantage of PC ventilation is dependent on patient position.

Pneumoperitoneum formation during laparoscopic surgery may be associated with hemodynamic changes, such as an increase in the heart's workload [20]. Pressure-controlled ventilation may have a stronger effect due to the increased mean airway pressure [21], which may have an adverse effect on haemodynamic variables via its effects on pleural pressure [2]. Despite a substantial increase in the mean airway pressure during PC breathing, no significant alterations in hemodynamic indicators were seen in this study. This could be due to the slight change in mean airway pressure. Balick-Weber et al. [2] quantified systolic and diastolic performance using transoesophageal echocardiography, with left ventricular wall stress serving as the primary end measure. Despite a statistically significant, albeit small, difference in mean airway pressure between PC and VC ventilation, the authors discovered that PC and VC ventilation were statistically associated with identical hemodynamic results. Comparing PC and VC ventilation with noninvasive monitoring during laparoscopic gynaecological surgery indicated comparable absence of impact on hemodynamic parameters [8].

CONCLUSION

For non-obese people undergoing laparoscopic cholecystectomy, we conclude that pressure-controlled ventilation is a safe alternative to volume-controlled ventilation.

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