ANALES MEDICOS
ASOCIACION MEDICA CENTRO MEDICO ABC

Vol. 52, Núm. 4
Oct. - Dic. 2007
pp. 174 - 180

Haemodynamic and respiratory outcomes for pressure controlled ventilation and volume-controlled ventilation in patients submitted to laparoscopic surgery

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ABSTRACT

Background: Mechanical ventilation strategies are used to prevent lung damage, optimizing gas exchange. Recently, has been described that mechanical support limited by volume and pressure reduces lung overdistention. The aim of our study was to compare pressure control and volume control modalities in patients underwent to different laparoscopic approaches. **Methods:** With local ethics committee approval and written informed consent, 40 patients (Class I/II ASA) undergoing elective laparoscopic surgery were included in the study. The patients were fasted from midnight before the day of surgery . Anesthesia was induce with phentanyl (2 µg/kg), propofol (2 mg/kg) and atracurium (150 µg/kg). Endotracheal intubation was performed after complete relaxation evaluated with train of four (TOF). Anesthesia was mantained with sevoflurane (1 MAC). Patients were randomized to receive PCV or VCV. **Results:** Haemodynamic parameters were similar in both groups during the different periods of time recorded. Systolic, diastolic and mean pressure were similar. During pneumoperitoneum SpO_2 increased up to 97.61 + 1.29 for PCV compared to 97.25 + 1.2 for VCV (p 0.368). Ten minutes after insuflation SpO_2 remained similar for both groups (p 0.368). **Conclusion:** In summary we conclude that PCV and VCV are both well tolerated ventilation modalities for patients submitted to laparoscopic surgery.

Key words: Pressure controlled ventilation, volume controlled ventilation, laparoscopic surgery, haemodynamic an respiratory outcomes.

RESUMEN

Las estrategias de ventilación mecánica son usadas para prevenir el daño pulmonar, optimizando el intercambio gaseoso. Recientemente se ha descrito que el soporte mecánico limitado por el volumen y la presión reduce la sobredistensión pulmonar. El objetivo de este estudio fue comparar la ventilación controlada por presión y por volumen en pacientes sometidos a cirugía laparoscópica. ***Material y métodos:*** *Previa aprobación del Comité de Ética e informe de consentimiento escrito y firmado, se incluyeron 40 pacientes (ASA I/II) programados para cirugía laparoscópica electiva. Los pacientes se encontraban en ayuno desde media noche antes del día de la cirugía. Se realizó inducción anestésica con fentanil (2 µg/kg), propofol (2 mg/kg) y atracurio (150 µg/kg). La intubación endotraqueal se realizó con relajación muscular completa, valorada por tren de cuatro. Se mantuvo anestesia con sevoflurano a 1 MAC. Los pacientes fueron asignados de manera aleatoria para recibir ventilación controlada por presión (VCP) o ventilación controlada por volumen (VCV).* ***Resultados:*** *Los parámetros hemodinámicos fueron similares en ambos grupos durante los diferentes periodos registrados. Las presiones sistólica, distólica y media fueron similares. Durante el neumoperitoneo la SpO_2 presentó un aumento de 97.61 + 1.29 para VCP comparado con 97.25 + 1.2 para VCV (p 0.368). Diez minutos después de la insuflación, la SpO_2 se mantuvo similar en los dos grupos.* ***Conclusión:*** *Tanto la VCP como la VCV son modalidades de ventilación bien toleradas para pacientes sometidos a cirugía laparoscópica.*

Palabras clave. *Ventilación controlada por presión, ventilación controlada por volumen, cirugía laparoscópica, alteraciones hemodinámicas y respiratorias.*

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Recibido para publicación: 06/12/07. Aceptado: 21/12/07.

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INTRODUCTION

Pressure positive mechanical ventilation was developed in the mild 20´s as a part of the support in anesthesia during thoracic surgery.[1] Recently, mechanical ventilation has been described to have many clinical utilities due to reduced breath work and the fact that it improves acidosis status and hypoxemia. Mechanical ventilation is a useful tool, but it has morbidity and mortality related to its employment. This is the reason for trying to find new strategies improving gas exchange and to reduce these complications.[2]

Morbidity and mortality associated to mechanical ventilation represents the effect on volume and pressure outcomes. We know that positive pressure causes acute lung injury.[3-6] It seems to be obvious that lung inflation causes injury if airway pressure is high enough. Webb and Tierney, ventilated mice during 1 hour at different levels of pressure observing moderate perivascular edema in those which received peak inspiratory pressure (PIP) at 30 cm/H_2O while those receiving 45 cm/H_2O developed severe hypoxia after the first hour.[7] Another cause of lung damage is lung overdistention; this peculiar condition causes an increased on vessels permeability and dysfunction on the surfactant, leading to lung bleeding and hyaline membrane development. The use of low tidal volume and inspiratory peak pressure decreases lung damage caused by overdistention.[8] On the other side, ventilation with volume and pressure at lower levels next to alveolar volume has been described as a cause of lung damage related to mechanical forces and subsequently affecting surfactant function associated to changes on the alveolar surface.[8,9] Since the early 90´s the use of mechanical ventilation has changed. Recently, the use of low tidal volumes reduced mortality associated to respiratory dystress.[10] Mechanical ventilation strategies are used to prevent lung damage, optimizing gas exchange. Recently, has been described that mechanical support limited by volume and pressure reduce lung overdistention.[11-15]

Haemodynamic changes associated to mechanical ventilation are caused by increasing on the mean intrathoracic pressure and reduction on the venous return and preload volume. Vascular resistance, also is increased and positive ventilation could cause direct compression on the heart.[16] There are four haemodynamic conditions associated, those are heart rate, pre-load volume, post-load volume and contractility. These conditions could be modified as result of lung volume and intrathoracic pressure. There are several mechanisms including tone autonomic changes, lung vascular resistance, direct mechanical compression and increased in the abdominal pressure.[16] Considering the need to maintain a healthy patient under mechanical ventilation during a very short time as occurs in elective surgical procedures (laparoscopic surgery) it is important to prevent lung damage. Mechanical ventilation during an anesthetic procedure could be performed in many forms.

Pressure controlled ventilation (PCV) and Volume controlled ventilation (VCV) are both an alternative modes of ventilation which are used widely in severe respiratory failure. Those ways of ventilations could be used in patients submitted to anesthesia procedures.

Laparoscopic surgery usually requires a pneumoperitoneum by insuflatting the abdominal cavity with carbon dioxide (CO_2).

Pneumoperitoneum for laparoscopic surgery has been shown to induce increased systemic arterial pressure and filling volumes. The interpretation of increased central venous and pulmonary capillary wedge pressures associated with pneumoperitoneum remains controversial.[16-20] They may in fact, reflect increased cardiac filling but may also be the consequence of elevated intrathoracic pressure due to increased intraabdominal pressure, and hence even result in reduced cardiac filling. The intravascular volume state, positioning and the amount of intraabdominal pressure appear to be important factors with respect to venous return and the interpretation of increased filling pressures.[6]

The aim of our study was to compare pressure control and volume control modalities in patients underwent to different laparoscopic approaches.

PATIENTS AND METHODS

With local ethics committee approval and written informed consent, 40 patients (Class I/II ASA) undergoing elective laparoscopic surgery were included in the study. None of the patients had history or signs of cardiopulmonary disease. The present study is a prospective, randomized, longitudinal and descriptive one.

Anesthesia. The patients were fasted from midnight before the day of surgery. Anesthesia was induce with fentanyl (2 μg/kg), propofol (2 mg/kg) and atracurium (150 μg/kg). Endotracheal intubation was performed after complete relaxation evaluated with train of four (TOF). Anesthesia was mantained with sevoflurane (1 MAC). Patients were randomized to receive PCV or VCV. In the VCV group tidal volume was adjusted to maintain 8 mL/kg (ideal body weight) without PEEP (positive end expiratory pressure). At the beginning PCV was given at 10 cm H_2O of peak pressure and during the third ventilation it was adjusted to maintain 8 mL/kg (ideal body weight) after that the pressure was modified only if the volume increases or decreases. Train of four monitoring was used to assess the depth of paralysis. If the train of four increased 30% it was administered only 20% of the initial dose from atracurium in both groups. During the study FiO2 was maintained at 60% (3 lts/minute). Respiratory rate was adjusted to obtain an end tidal CO_2 of 30 mm Hg + 2. The lungs were ventilated using a Datex Ohmeda Aestiva 5000 ventilator.

Once steady 5 minutes after intubation state was achieved, respiratory parameters (plateau pressure, end tidal CO_2 inspiratory and expiratory, inspiratory and expiratory tidal volume, minute volume, lung compliance, respiratory frequency and main airway pressure) Peak airway pressure (Paw) and mean airway pressure (Pmaw) were recorded during each mode of ventilation. Inspiratoy Plateau was established by activating the inspiratory hold on the ventilator. Inspiratory plateau pressure (Pplt) was measured during the last 0.3 s of each hold maneuver. The haemodynamic outcomes such as heart rate, mean arterial pressure, systolic pressure, SPO_2 and diastolic pressure were measured.

Statistical analysis. Data were analyzed by a biostatiscian using SPSS 13.0 for windows software and are presented as mean + standard deviation. The significance of differences was tested by a two way analysis of variance for repeated measurements. A p value < 0.05 was considered statistically significant.

RESULTS

Patients data are shown in *table I*. We evaluated 40 consecutively patients randomized to receive PCV or VCV (20 and 20 respectively). Age, gender, weight, height, BMI and ASA were similar in both groups. We found 4 non heavy smokers in each group. Surgical procedure were similar for both groups *(Table II)*. Surgical time was of 1.8 + 0.80 and 1.7 + 0.74 for PCV and VCV respectively. All patients completed the study protocol which allowed a comparative analysis of the two modes of ventilation.

Table I. Clinical characteristics.

	PCV	*VCV*	*p*
Age*	43 ± 10	42 ± 9	0.341
Sex	F 10 M 10	F 10 M 10	0.398
Weight*	75 ± 16	75 ± 17	0.665
Height*	1.67 ± 0.86	1.69 ± 0.97	0.796
BMI*	26 ± 3	25 ± 4	0.565
ASA	I-II	I-II	0.716
Smokers	4	4	

PCV = Pressure controlled ventilation. VCV = Volume controlled ventilation. F = Female. M = Male. BMI = Body mass index.
* Values are expressed as median and standard deviation

Respiratory outcomes. Baseline peak pressure was of 14.15 + 2.79 for PCV and 16.40 + 4.62 for VCV group (p 0.43). During pneumoperitoneum, peak pressure increased up to 15.90% (PCV) compared to 18.56% in the VCV arm (p 0.004). Peak airway pressure after ten minutes from pneumoperitoneum was 15.5 + 3.23 for PCV and 17.90 + 4.65 for VCV (p 0.59).

Baseline plateau pressure was of 13.85 + 2.68 and 15.80 + 4.47 for PCV and VCV respectively. During pneumoperitoneum Plateau pressure was increased up to 18.09 + 3.27 and 21.19 + 4.85 for PCV and VCV (p 0.017) and after pneumoperitoneum PCV exhibited a Plateau pressure of 14.90 + 3 compared with 17.4 + 4.85 in VCV.

Lung compliance was similar before insuflation between PCV and VCV .During insuflation, it was higher in PCV patients (36.73 + 8.49 compared to 32.34 + 7.8, p 0.052).

Baseline mean airway pressure was higher in the PCV group (6.45 + 1.14 versus 5.86 + 1.42). During pneumoperitoneum and after itself mean airway pressure was of 7.79 + 1.36 versus 7.10 + 1.47 and 6.65 + 1.22 versus 5.95 + 1.43 for PCV and VCV respectively *(Table III)*.

Baseline expiratory volume was of 529 + 79 be-

Table II. Surgical procedures and PCV/VCV.

	PCV	*VCV*
Cholecystectomy	12	9
Funduplication	7	8
Inguinal Hernioplasty	1	3
Surgical time*	1.80 ± 0.80	1.70 ± 0.74
Sevofluorane	13	11
Desfluorane	7	9
Atracurium	16	14

* Values are expressed as median and standard deviation.

Table III. Respiratory outcomes during PCV and VCV.

	*PCV**	*VCV**	*p*
PIP baseline	14.15 ± 2.79	16.40 ± 4.62	.043
PIP pneum	18.58 ± 3.32	22.03 ± 5.03	.004
PIP post-pneumo	15.55 ± 3.23	17.90 ± 4.65	.059
PP baseline	13.85 ± 2.68	15.80 ± 4.47	.093
PP pneum	18.09 ± 3.27	21.19 ± 4.85	.017
PP post-pneumo	14.90 ± 3.00	17.40 ± 4.85	.063
Compl baseline	49.60 ± 11.49	45.80 ± 14.46	.356
Compl pneum	36.73 ± 8.49	32.34 ± 7.80	.052
Compl post-pneum	44.65 ± 12.20	40.30 ± 10.29	.208
Paw baseline	6.45 ± 1.14	5.85 ± 1.42	.117
Paw pneum	7.79 ± 1.36	7.10 ± 1.47	.058
Paw post-pneum	6.65 ± 1.22	5.95 ± 1.43	.069

PCV = Pressure controlled ventilation. VCV = Volume controlled ventilation.PIP = Peak inspiratory pressure. PP = Plateau pressure.
Compl = Lung compliance. Paw = Main airway pressure. pneum = Mean time during pneumoperitoneum.
* Values are expressed as median and standard deviation

Table IV. Tidal volume, respiratory rate and minute volume.

	*PCV**	*VCV**	*p*
EV baseline	529.00 ± 79.53	548.00 ± 107.12	0.492
EV pneum	545.00 ± 81.43	552.00 ± 93.43	0.781
EV post-pneum	541.00 ± 91.43	569.00 ± 103.61	0.387
RR baseline	10.65 ± 1.22	11.35 ± 1.36	0.167
RR pneum	11.33 ± 1.44	12.13 ± 1.33	0.107
RR post-pneum	11.65 ± 1.72	12.30 ± 1.78	0.281
MV baseline	5,671.00 ± 1281	6,206.00 ± 1,450.00	0.234
MV pneum	6,215.00 ± 1450	6,677.00 ± 1,199.00	0.295
MV post-neum	6,330.00 ± 1530	6,973.00 ± 1,523.00	0.228

PCV = Pressure controlled ventilation. VCV = Volume controlled ventilation.
EV = Expiratory volume. RR = Respiratory rate. MV= Minute volume. pneum = Mean time during pneumoperitoneum.
* Values are expressed as median and standard deviation.

Table V. Hemodynamic outcomes.

	*PCV**	*VCV**	*p*
HR pneum	74.15 ± 14.37	80.06 ± 13.29	0.156
SBP pneum	114.71 ± 12.10	116.82 ± 12.40	0.593
DBP pneum	75.81 ± 13.53	77.23 ± 10.50	0.718
$ETCO_2$ pneum	30.18 ± 1.36	29.70 ± 1.18	0.224
SpO_2 baseline	97.25 ± 0.97	97.25 ± 2.07	0.937
SpO_2 pneu	97.61 ± 1.29	97.25 ± 1.88	0.298
SpO_2 post-pneum	97.85 ± 1.53	97.55 ± 1.46	0.368

PCV = Pressure controlled ventilation. VCV = Volume controlled ventilation.
HR = Heart rate. SBP = Systolic blood pressure. DBP = Diastolic blood pressure.
* Values are expressed as median and standard deviation.

fore pneumoperitoneum, 545 + 81 during pneumoperitoneum and 541 +/- 91 after pneumoperitoneum for PCV versus 548 +/-107, 552 + 93.4 and 569 + 103 for VCV at the same stages *(Table IV)*. Minute volume in PCV and VCV is seen in *table IV*.

Haemodynamic outcomes. Haemodynamic parameters were similar in both groups during the different periods of time recorded. Systolic, diastolic and mean pressure were similar. Baseline SpO_2 was similar for both groups (p 0.937) *(Table V)*. During pneumoperitoneum SpO_2 increased up to 97.61 + 1.29 for PCV compared to 97.25 + 1.2 for VCV (p 0.368). Ten minutes after insuflation SpO_2 remained similar for both groups (p 0.368) *(Table V)*.

DISCUSSION

Ventilation modes are often described as volume-controlled or pressure controlled depending on wether tidal volume or maximum airway pressure is the specified target for the end of active inspiration. In current practice, pressure controlled modes build pressure rapidly and attempt to maintain pressure constant through the remainder of the high pressure phase. Decelerating inspiratory flow characterizes such rectilinear pressure waveforms, characteristic that may improve the distribution of ventilation and limit the maximal inspiratory and regional pressure among lung units with heterogeneous ventilatory time constants.[21,22]

Pressure controlled ventilation (PCV) is an alternative mode of ventilation which is used widely in severe respiratory failure. PCV has been shown to improve arterial oxygenation and decrease peak airway pressure because of its decelerating inspiratory flow.[23] Uniform distribution of inspired gas with PCV is the major cause of better arterial oxygenation in patients with respiratory failure.[24-27] Volume controlled ventilation (VCV) in the other side is the traditional method of performing procedures such as one lung anesthesia. If the method of ventilation involves excessive amounts of airway pressure, vascular resistance of the dependent lung may be increased because of compression of intra-alveolar vessels.[28]

Our study was designed to evaluate the outcomes in terms of respiratory parameters in patients underwent to laparoscopic surgery.

Laparoscopic surgery is usually performed by the intra-abdominal insuflation of carbon dioxide, i.e. pneumoperitoneum. Insuflation of carbon dioxide intra-abdominally causes a rise in arterial carbon dioxide tension ($PaCO_2$) and possibly acidosis, by diffusion through peritoneum. In order to maintain normocapnia, the respiratory rate often needs to be increased intraoperatively. In cases of severe hypercapnia or acidosis, conversion of the laparoscopic approach into an open procedure has been reported.[29] It has already been demonstrated that anesthesia per se results in a reduced functional residual capacity[30,31] and shifting of the diaphragm cranially. Furthermore, atelectasis development occurring in dependent regions of the lungs during anesthesia impairs the ventilation-perfusion match. This has been evaluated by the multiple inert gas technique as increased shunting of lung blood flow.[32] Based on indirect methods it has been claimed that pneumoperitoneum causes an increase in dead space in pigs and in healthy patients.[33,34] At our study we compared 2 modalities of ventilation over patients undergoing to laparoscopic surgery. VCV offers the possibility to reduce airway peak pressure at tidal volume of 8 mL/kg maintaining an adequate gas exchange and avoiding alveolar overdystention. Campbell et al, previously reported that PCV is not better than VCV.[20] We found that during pneumoperitoneum plateau pressure increased much less in the PCV mode ($p < 0.017$). Lung compliance is another important outcome in anesthesia ventilation. Previous reports described a compliance reduction during pneumoperitoneum.[35] We reported an slighty better outcome in Lung compliance for those patients underwent to PCV (49 cm H_2O *vs* 45).

One problem related to PCV is the possibility to reduce tidal volume and subsequently minute volume, impairing gas exchange. At our study we maintained a tidal volume upper 8 mL/kg requiring an slighty lower respiratory rate in the PCV group. In summary we conclude that PCV and VCV are both well tolerated ventilation modalities for patients submitted to laparoscopic surgery.

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