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Pressure Support Ventilation versus *Continuous Positive Airway Pressure with the Laryngeal Mask Airway*

A Randomized Crossover Study of Anesthetized Adult Patients

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Background: **The authors tested the hypothesis that pressure support ventilation (PSV) provides more effective gas exchange than does unassisted ventilation with continuous positive airway pressure (CPAP) in anesthetized adult patients treated using the laryngeal mask airway.**

Methods: **Forty patients were randomized to two equal-sized crossover groups, and data were collected before surgery. In group 1, patients underwent CPAP, PSV, and CPAP in sequence. In group 2, patients underwent PSV, CPAP, and PSV in sequence. PSV comprised positive end expiratory pressure set at 5 cm H_2O and inspiratory pressure support set at 5 cm H_2O above positive end expiratory pressure. CPAP was set at 5 cm H_2O. Each ventilatory mode was maintained for 10 min. The following data were recorded every minute for the last 5 min of each ventilatory mode and the average reading taken: end tidal carbon dioxide, oxygen saturation, expired tidal volume, leak fraction, respiratory rate, noninvasive mean arterial pressure, and heart rate.**

Results: **In both groups, PSV showed lower end tidal carbon dioxide ($P < 0.001$), higher oxygen saturation, ($P < 0.001$), and higher expired tidal volume ($P < 0.001$) compared with CPAP. In both groups, PSV had similar leak fraction, respiratory rate, mean arterial pressure, and heart rate compared with CPAP. In group 1, measurements for CPAP were similar before and after PSV. In group 2, measurements for PSV were similar before and after CPAP.**

Conclusion: **The authors concluded that PSV provides more effective gas exchange than does unassisted ventilation with CPAP during LMA anesthesia while preserving leak fraction and hemodynamic homeostasis. (Key words: Gas exchange; respiratory function.)**

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SPONTANEOUS breathing is the most popular mode of ventilation with the laryngeal mask airway (LMA),[1] but provides less effective gas exchange than does positive pressure ventilation (PPV).[2] Pressure support ventilation (PSV) is a form of partial ventilatory support in which each spontaneous breath is assisted to an extent that depends on the level of a constant pressure applied during inspiration.[3,4] Bosec *et al.*[5] showed that PSV improves gas exchange in anesthetized intubated patients; but, there is only one anecdotal report of PSV usage with the LMA.[6] In the following randomized crossover study, we tested the hypothesis that PSV provides more effective gas exchange than does unassisted ventilation with continuous positive airway pressure (CPAP) in anesthetized adult patients treated using the LMA.

Methods

Forty consecutive adult patients (American Society of Anesthesiologists physical status I or II, aged 18-80 yr) undergoing peripheral musculoskeletal surgery in which the LMA was considered to be suitable were studied. Ethics committee approval and written informed consent were obtained from the Leopold-Franzens University and patients, respectively. A standard anesthesia protocol was followed and routine monitoring was applied. Patients were induced with 2 μg/kg fentanyl and 2.5 mg/kg propofol. Maintenance included 6 $mg \cdot kg^{-1} \cdot h^{-1}$ propofol in oxygen and air, with the inspired oxygen concentration adjusted to 30%. One experienced LMA user (> 1,000 uses) inserted or fixed the LMA (size 5, all patients)[7] accord-

Table 1. End-tidal C_{O_2}, Oxygen Saturation, Expired Tidal Volume, Leak Fraction, Respiratory Rate, Mean Arterial Pressure, and Heart Rate during Continuous Positive Airway Pressure and Pressure Support Ventilation for the Two Crossover Groups

	Group 1			Group 2		
	CPAP*	PSV†	CPAP‡	PSV*	CPAP†	PSV‡
n	20	20	20	20	20	20
PET_{CO_2} (mmHg)	50 (48–51)	40 (39–41)	50 (48–51)	41 (40–41)	49 (48–49)	40 (40–41)
Sp_{O_2} (%)	96.6 (96.0–97.1)	98.1 (97.8–98.5)	96.7 (96.1–97.3)	98.2 (97.9–98.6)	96.6 (96.1–97.1)	98.1 (97.7–98.59)
VTExp (ml)	414 (374–453)	635 (561–708)	417 (373–462)	660 (635–686)	422 (403–442)	658 (630–686)
LF (%)	1 (0–1)	1 (0–1)	1 (0–1)	1 (0–1)	1 (0–1)	1 (0–1)
RR (breaths/min)	11 [9–16]	11 [7–16]	11 [9–16]	11 [7–17]	11 [7–17]	11 [7–16]
MAP (mmHg)	85 (83–87)	85 (83–88)	85 (83–88)	85 (82–88)	85 (82–88)	85 (82–88)
HR (beats/min)	67 (64–70)	67 (64–70)	68 (65–71)	68 (64–72)	69 (65–73)	69 (65–72)

Data are mean (95% CI) or [range].

Ventilatory mode sequence for groups:

* First, 10 min.

† Second, 10 min.

‡ Third, 10 min.

CPAP = continuous positive airway pressure; PSV = pressure support ventilation; VTExp = expired tidal volume; LF = leak fraction; RR = respiratory rate; MAP = mean arterial pressure; HR = heart rate.

ing to the manufacturer's instructions (Laryngeal Mask Co., Henley-on-Thames, UK).[8] The volume of air in the cuff was adjusted so the airway sealing pressure was more than 15 cm H_2O. The lungs were manually inflated until spontaneous breathing resumed. Mechanical ventilation was begun (Evita 4; Draeger Medizintechnik GmbH, Luebeck, Germany) and the patients were allocated randomly to two crossover groups. In group 1 (n = 20), patients underwent CPAP, PSV, and CPAP in sequence. In group 2 (n = 20), patients underwent PSV, CPAP, and PSV in sequence. PSV comprised positive end expiratory pressure (PEEP) set at 5 cm H_2O and pressure support set at 5 cm H_2O above PEEP. CPAP was set at 5 cm H_2O. Pressure support was initiated when inspiratory flow reached 3 l/min. Each ventilatory mode was maintained for 10 min. No minimal respiratory rate (RR) or apnea backup was set on the ventilator. The following data were recorded by an unblinded observer once every minute for the last 5 min for each ventilatory mode and the average reading used for analysis: end tidal carbon dioxide (ET_{CO_2}), oxygen saturation (Sp_{O2}), expired tidal volume (VTExp), leak fraction (LF), RR, noninvasive mean arterial pressure, and heart rate. Sp_{O2} was measured using the finger pulse oximeter. Spirometry was measured from the inspiratory and expiratory limb of the anesthesia circuit. In addition, epigastric auscultation was performed to detect air entering the stomach. Measurements were made before surgery. LF was determined by noting the difference between inspired and expired tidal volume. Statistical analysis was performed using the Bonferroni corrected *t* test. Significance was taken as $P < 0.05$.

Results

The mean (range) age, height, and weight was 36 yr (21-60 yr), 171 cm (158-188 cm), and 74 kg (50-110 kg), respectively. The male:female ratio was 19:21. There were no demographic differences between groups. Data are presented in table 1. All data were normally distributed. In both groups, PSV had lower ET_{CO_2} ($P < 0.001$), higher Sp_{O2} ($P < 0.001$), and higher VTExp ($P < 0.001$) compared with CPAP. In both groups, PSV had similar LF, RR, mean arterial pressure, and heart rate compared with CPAP. In group 1, measurements for CPAP were similar before and after PSV. In group 2, measurements for PSV were similar before and after CPAP. Data for CPAP were similar between groups and for PSV were similar between groups. Gastric insufflation was not detected.

Discussion

Our data show that PSV provides more effective gas exchange than unassisted ventilation with CPAP during anesthesia with the LMA. Minute volume increased by 50%, but $ETCO_2$ only decreased by 20% (50 - 40 mmHg), suggesting that 30% of the additional ventilation is wasted. This is probably related to an increase in alveolar dead space. We found that PSV improves Sp_{O2} by approximately 1.5%. This may be related to the increase in alveolar ventilation because the fraction of inspired oxygen was low. PSV and CPAP both cause an increase in mean airway pressure, resulting in a larger lung volume available for gas exchange. Interestingly, we found no reduction in RR with PSV. A reduction in RR with PSV has been reported in intubated critically ill patients[9] and in awake healthy subjects breathing through a mouth piece.[10] It may be that higher levels of PSV would have triggered a reduction in RR in our patients.

We found that LF was less than 1% and that gastric insufflation did not occur. Devitt *et al.*[11] measured LF and gastric insufflation at peak airway pressures of 15-30 cm H_2O and found that LF was 13-27% and gastric insufflation was 2-35%. Berry *et al.*[12] reported leak fractions of less than 3% with the LMA at tidal volumes of 10 ml/kg. Peak airway pressures did not exceed 10 cm H_2O and were at least 5 cm H_2O below airway sealing pressure. Air leakage and gastric insufflation are highly unlikely at this level of peak pressure and airway sealing pressure.

We detected no differences in cardiovascular effects between PSV and CPAP. This is not surprising because the average intrathoracic pressure changes would have been similar between groups. No differences in cardiovascular effects were detected when comparing PPV with spontaneous breathing during LMA anesthesia.[2] Finally, we did not measure work of breathing, but this is reduced during pressure support in intubated patients,[13] and we speculate that this also occurs during PSV with the LMA.

We conclude that PSV provides more effective gas exchange than does unassisted ventilation with CPAP during anesthesia with the LMA while preserving LF and hemodynamic homeostasis.

References

1. Verghese C, Brimacombe J: Survey of laryngeal mask usage in 11910 patients: Safety and efficacy for conventional and nonconventional usage. Anesth Analg 1996; 82:129-33

2. Keller C, Sparr HJ, Luger TJ, Brimacombe J: Patient outcomes with positive pressure versus spontaneous ventilation in non-paralysed adults with the laryngeal mask. Can J Anaesth 1998; 45:564-7

3. McIntyre NR: Respiratory function during pressure support ventilation. Chest 1986; 89:677-83

4. Brochard L, Pluskwa F, Lemaire F: Improved efficacy of spontaneous breathing with inspiratory pressure support. Am Rev Respir Dis 1987; 136:411-5

5. Bosek V, Roy L, Smith RA: Pressure support improves efficiency of spontaneous breathing during inhalation anesthesia. J Clin Anesth 1996; 8:9-12

6. Groudine SB, Lumb PD, Sandison MR: Pressure support ventilation with the laryngeal mask airway: A method to manage severe reactive airway disease postoperatively. Can J Anaesth 1995; 42:341-3

7. Brimacombe J, Keller C: Laryngeal mask airway size selection in males and female: Ease of insertion, oropharyngeal leak pressure, pharyngeal mucosal pressures and anatomical position. Br J Anaesth 1999; 82:703-7

8. Brimacombe J, Brain AIJ, Berry A: The Laryngeal Mask Airway Instruction Manual. Henley-on-Thames, Intavent Research Limited, 1996

9. Hörmann C, Baum M, Putensen C, Putz G: Tidal volume, breathing frequency, and oxygen consumption at different pressure support levels in the early stage of weaning in patients without chronic obstructive pulmonary disease. Intensive Care Med 1992; 18:226-30

10. Lofaso F, Isabey D, Lorino H, Harf A, Scheid P: Respiratory response to positive and negative inspiratory pressure in humans. Respir Physiol 1992; 89:75-88

11. Devitt JH, Wenstone R, Noel AG, O'Donnell RRT: The laryngeal mask airway and positive-pressure ventilation. ANESTHESIOLOGY 1994; 80:550-5

12. Berry A, Brimacombe J, Keller C, Verghese C: Pulmonary airway resistance with the endotracheal tube versus laryngeal mask airway in paralyzed anesthetized adult patients. ANESTHESIOLOGY 1999; 90:295-7

13. Christie JM, Smith RA: Pressure support ventilation decreases inspiratory work of breathing during general anesthesia and spontaneous ventilation. Anesth Analg 1992; 75:161-71