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Original Contribution

A comparison of 3 ventilation strategies in children younger than 1 year using a Proseal laryngeal mask airway: a randomized controlled trial☆,☆☆

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Abstract

Study Objective: To determine quantitative differences in several routinely measured ventilation parameters using a standardized anesthetic technique and 3 different ventilation modalities in patients younger than 1 year with a ProSeal laryngeal mask airway (PLMA).

Design: Randomized prospective study.

Setting: Tertiary care pediatric hospital.

Patients: Thirty-nine American Society Anesthesiologists classifications 1 to 2, pediatric patients younger than 1 year.

Interventions: Three different ventilation strategies (spontaneous ventilation [SV], pressure support ventilation [PSV], and pressure-controlled ventilation [PCV]) were randomly applied to patients who underwent a standardized mask induction with sevoflurane/oxygen and propofol 2 mg/kg and fentanyl 2 μg/kg administered intravenously followed by PLMA insertion. Patients were maintained on sevoflurane and N_2O.

Measurements: We measured the differences in end-tidal CO_2 ($ETCO_2$), tidal volume (TV), and respiratory rate (RR) over time between SV, PSV, and PCV. These data were recorded at 5-minute intervals.

Main Results: $ETCO_2$ (mm Hg) was not significantly higher in the SV vs PSV ($P = 2.11$) and SV vs PCV ($P = .24$). TV (mL/kg) was significantly lower in SV vs PSV ($P < .005$) and SV vs PCV ($P < .005$). RR was not significantly higher in SV vs PSV ($P = .43$), but was significantly higher in SV vs PCV ($P < .005$). Three patients in the SV group and 1 patient in the PSV group failed to initiate SV and required PCV and were thus excluded from analysis.

Conclusions: All 3 modes of ventilation using a PLMA were safe in children younger than 1 year. Although we did not observe a statistically significant increase in $ETCO_2$, differences in TV and RR, and the small but

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significant incidence of apnea may make PSV or PCV more optimal ventilation strategies in children younger than 1 year when using a PLMA.

1. Introduction

The Proseal laryngeal mask airway (PLMA; Teleflex, Morrisville, NC) has been reported as a safe and effective supraglottic airway device in children younger than 1 year [1-4]. The modified cuff design of the PLMA allows for more consistent administration of positive pressure ventilation in most patients [5]. To date, there are no studies in this young age group comparing spontaneous ventilation (SV) with either pressure support ventilation (PSV) or pressure-controlled ventilation (PCV) during elective surgery. It is clear from a number of previously published studies that pediatric patients 1 to 6 years old who are allowed to spontaneously ventilate without assistance have consistently higher end-tidal CO_2 ($ETCO_2$) and smaller tidal volumes (TVs) [6-8]. The increased chest wall compliance, larger closing volumes, and increased sensitivity to specific and combined anesthetic agents in this younger patient population could further exacerbate the degree of alveolar hypoventilation in this cohort during SV; however, this has not been quantified.

SV may be useful in certain brief cases. It offers the advantage of potentially titrating analgesics, lack of need to set the ventilator, and no need to wait for the return of SV at the end of the anesthetic [9,10]. In longer procedures, however, there may be an increased risk of atelectasis, clinically significant hypoventilation, and significant arteriolar hypercapnia as surgical duration increases [11,12]. In contrast, PSV or PCV can reduce the work of breathing in this population and potentially improve both $PaCO_2$ homeostasis and increase TVs [6,7,13].

Several studies have demonstrated the use of the PLMAs in children using various ventilation modalities [6,7,13]. A study by Lim et al [6] compared SV and PSV by measuring TV and $ETCO_2$ in young children ventilated with a PLMA for the duration of the procedure. However, their study did not directly compare the effects of SV or PSV to a control group using PCV over the entire anesthetic period. Also, none of these studies attempted to specifically evaluate quantitative differences in children younger than 1 year. We published an earlier study looking at PCV, PSV, and SV in older children with findings similar to those of Lim et al [6] and von Goedecke et al [8]. These studies showed an increase in $ETCO_2$ and a significant reduction in TV in patients breathing spontaneously with a PLMA. However, these studies were all performed in older children [6-8]. Given these findings in older pediatric patients, we hypothesized that children younger than 1 year would also have improved respiratory parameters over time using PSV and PCV when compared with those who are allowed to breathe spontaneously with a PLMA while undergoing outpatient urologic surgery.

2. Methods

This study was approved by the Wake Forest University Health Sciences Institutional Review Board. After obtaining informed consent from a parent/legal guardian, 39 American Society Anesthesiologists (ASA) classification 1 and 2 infants (1-11 months of age) scheduled for outpatient urology procedures under general anesthesia were enrolled in the study. Exclusion criteria included inpatients, ASA physical status ≥3, formerly premature infants or infants <44 weeks post–conceptual age, emergency case status, or family history of malignant hyperthermia.

Subjects were not premedicated. Once in the operating room standard monitors were applied including pulse oximetry, electrocardiogram, blood pressure, capnography, and end-tidal gas analysis. All subjects were induced with 8% sevoflurane in 8 L/min fresh gas flow of oxygen. After inhalational induction, intravenous access was obtained. Each patient was then given propofol 2 mg/kg, fentanyl 2 μg/kg, and atropine 0.1 mg to facilitate placement of the PLMA. Thirty seconds after administration of these drugs, an appropriate-sized PLMA was placed and the cuff inflated. PLMA size and the number of placement attempts were recorded.

Proper placement of the PLMA was confirmed by symmetrical chest excursion with bag mask ventilation, an appropriately squared off $ETCO_2$ tracing, bilateral chest auscultation, absence of an audible leak at 20 cm H_2O, and the absence of obvious abdominal distention. An oropharyngeal leak and PLMA cuff pressures were not measured. A suction catheter was inserted into the esophageal conduit of the PLMA to suction the stomach. The sevoflurane was set to an inspired concentration of 3%, and the fresh gas flows of N_2O and O_2 were set to 2 L/min each. Gas analysis was performed on a Datex-Ohmeda S5 anesthesia monitoring system (Datex-Ohmeda, Inc, Madison, WI). The patients were managed throughout using a Datex-Ohmeda Aestiva 5 anesthesia machine (Datex-Ohmeda, Inc) outfitted with PSV-Pro (GE Healthcare, Inc, Wauwatosa, WI).

After consent, subjects were randomly assigned using an opaque envelope randomization scheme to 1 of 3 groups, SV, PSV, or PCV. Subjects randomized to the SV group were allowed to breathe spontaneously and were not placed on the ventilator. If patients in the SV and PSV group were initially apneic, they were assisted with occasional manual breaths until return of SV effort. If patients randomized to the SV group maintained a TV consistently ≤4 mL/kg, a single manually assisted breath was administered every 5 minutes to determine an accurate $ETCO_2$ value more reflective of the alveolar concentration of CO_2.

Subjects randomized to the PSV group were also assisted with manual ventilation and immediately placed on the