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Research Article

Does pressure support ventilation improve the postoperative outcome of adeno-tonsillectomy patients? A prospective randomized trial

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Abstract *Background:* Spontaneous ventilation (SV) is used for adeno/tonsillectomy in children. However, inhalational anesthetics produce dose dependent decrease in minute ventilation. We tested the impact of PSV on awakening time, and length of PACU stay.
Methods: 34 patients were randomized into two groups; PS ventilation group and SV group. Premedication and induction were similar in both groups. Patients in PS group were ventilated with P_{insp} set to deliver 8 ml/kg V_T, keeping $ETCO_2$ between 35 and 45 mmHg. Any episodes of hypoventilation were recorded and corrected by manual support of ventilation.
Upon completion of surgery, time-to-extubate was recorded. Length of PACU stay, agitation and CHEOPS scores, PONV and desaturation episodes were also recorded. Results are presented as mean (SD), median (interquartile range), or number of patients as appropriate. A P value < 0.05 was considered significant.

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Results: Extubation time (min) [mean (SD)] was longer in SV group than PS group [*7.8* (*2.1*) vs. *5.5(1.4), P < 0.001*]. In the SV group 9 patients had episodes of hypoventilation that necessitated manual assist of ventilation. Pain scores were higher in SV group than PS group. Duration of stay in PACU [mean (SD)] in minutes was longer in SV group than PS group [*44.3*(*7.4*) vs. *39.4*(*5.7*), *P = 0.02*]. All but one patient in the PS group needed postoperative rescue meperidine analgesia. The mean (SD) time needed for rescue meperidine analgesia was *27.1(8.9*) in PS group and *21.8(9.4*) in SV group (*P = 0.04)*.

Conclusion: PSV carries the advantages of overcoming the effects of narcotics and inhaled anesthetics on spontaneously ventilated adeno-tonsillectomy patients. They suffer less pain and spend less time in the PACU.

1. Introduction

Adenotonsillectomy in children is a very common surgical procedure, needing dedicated and expert anesthetic attention. Whereas a lot of clinical studies on important aspects of anesthetic handling may be identified in recent years, there will be still controversies which may not be fully solved [1]. The core principles of anesthesia for adenotonsillectomy are to maintain a sufficient depth of anesthesia to allow the introduction of a mouth gag, and prevent reflex-induced hypertensive responses, tachycardia, and hypertension. During the procedure, intermittent positive-pressure ventilation or spontaneous ventilation can be used; at the end, a careful inspection for bleeding should be performed [2].

With sevoflurane, tidal volume and the slopes of the CO_2 response curves decrease and $PaCO_2$ increases with increasing depth of anesthesia. A compensatory increase in respiratory frequency does not prevent a decrease in minute volume with increasing depth of anesthesia [3,4].

Pressure support (PS) ventilation is a form of partial ventilatory support in which each spontaneous breath is assisted to an extent that depends on the level of pressure applied during inspiration. PS ventilation improves gas exchange in anesthetized patients whether their airway is intubated or managed by laryngeal mask airway (LMA) [5–7]. To date, PSV was not studied as an anesthetic mode of ventilation in the adeno/tonsillectomy patient population. PSV carries the advantages of overcoming the effects of narcotics and inhaled anesthetics on ventilation [5].

1.1. Aim of the work

In the following randomized study, we tested the hypothesis that PSV as an anesthetic mode of ventilation for patients undergoing adeno/tonsillectomy results in a shorter awakening time and length of PACU stay.

1.2. Methods

After approval of the Institutional Ethical Committee and parents'/guardian informed consent, 51 patients with American Society of Anesthesiologists (ASA) physical status I–II, who were scheduled to undergo an adeno/tonsillectomy under general anesthesia, were enrolled in this study, from December 2010 till November 2011. Children with cognitive or developmental disorders were excluded from the study. Six children met our exclusion criteria and parents of 11 patients refused participation. Thirty-four patients were randomized, by a computer-generated schedule, into 2 groups: Pressure Support ventilation (PS) group ($n = 17$) and Spontaneous Ventilation (SV) group ($n = 17$). No patient was excluded from the study.

Patients were premedicated with midazolam 20 min before admission to OR (0.5 mg/kg PO with an upper limit of 20 mg) for preoperative anxiolysis. Standard monitors; electrocardiography (ECG), non-invasive blood pressure (NIBP), end-tidal capnography ($ETCO_2$), and peripheral oxygen saturation (SPO_2) were used for all patients. General anesthesia was induced by the inhalation of sevoflurane (6–8%) and if needed, succinylcholine (0.6 mg/kg IV) was administered to facilitate tracheal intubation [8,9]. Anesthesia was maintained with sevoflurane in 2 L oxygen: air mixture of 1:1. Inspired sevoflurane was adjusted to maintain an expired MAC in the range of 1.5–2 to prevent intraoperative movement. Dexamethasone 0.15 mg/kg intravenously was given to patients for post-operative nausea and vomiting (PONV) prophylaxis. Fentanyl 1 mcg/kg IV and intravenous infusion of paracetamol 15 mg/kg were administered after endotracheal intubation for both groups. If heart rate (HR) and/or mean blood pressure (MBP) increased more than 20% for 2 min, additional bolus dose of fentanyl 0.5 mcg/kg i.v. every 5 min was administered with an upper limit of 3 mcg/kg.

After the induction of anesthesia patients were assigned to either PS ventilation group, or SV group. Dräger Primus® (Drägerwerk AG & Co., KGaA, Lübeck, Germany) was used for the ventilation in both groups. Patients in PS group were ventilated with PSV mode; inspiratory pressure (P_{insp}) was set to deliver near normal tidal volume ($V_T = 8$ ml/kg) [6] with a backup respiratory rate of 10 breaths per minute targeting to keep the $ETCO_2$ in the physiological range; 35–45 mmHg. Any episodes of hypoventilation; $ETCO_2 > 55$ mm Hg and/or hypoxia; $SPO_2 < 92\%$, were recorded and corrected by manual support of ventilation.

Upon completing the surgical procedure, defined by the release of the mouth gag, careful inspection and laryngoscopy was undertaken to ensure no blood clots were present. The administration of sevoflurane was stopped, and manual ventilation was then performed with 100% oxygen at 6 L/min. Extubation was performed when the patients' gag reflex was regained and they showed facial grimaces or purposeful-appearing motor movements. Time to extubation was recorded as the time from the release of the mouth gag till the time at which trachea was extubated. The time span from the start of mask ventilation until the extubation time was recorded as the duration of anesthesia, whereas the time span between

Table 1 Modified *CHEOPS* pain score (0–10).

Score	0	1	2
Cry	No	Crying, moaning	Scream
Facial	Smiling	Composed	Grimace
Verbal	Positive	None or other complaint	Pain complaint
Torso	Neutral	Shifting, tense, upright	Restrained
Legs	Neutral	Kick, squirm, drawn-up	Restrained

the insertion and removal of the mouth gag was recorded as the duration of surgery.

Patients were transferred to the PACU and an anesthetist blinded to the anesthetic technique followed all patients throughout their PACU stay. Pain was assessed by using Children's Hospital of Eastern Ontario Pain Scale (CHEOPS) score (Table 1) [10], and if patients scored more than three, 1 mg/kg meperidine i.v. was given. The need for rescue opioid, and the time needed for its administration, were recorded, as well as the incidence of PONV.

Agitation scores were graded on a five-point scale that defined the patient's behavior in the PACU. The scores 1–5 corresponded to "sleeping, awake and calm, irritable and crying, inconsolable, and restless and disoriented" [11].

Continuous pulse oximetry monitors were set to alarm at $SpO_2 < 92\%$. Any alarm event, when not attributed to artifact due to movement or removal of the saturation monitor probe, was recorded as a desaturation. Both the investigator and the primary PACU nurse assigned to the subject confirmed each desaturation event. The number of oxygen desaturations ($SpO_2 < 92\%$) was recorded.

PONV was defined as any episode of frank emesis, dry heaves, or subjective complaint of nausea (older, verbal children).

Duration of recovery in the PACU was measured from time of arrival to the PACU until the notation of "discharge ready" in the patient's chart. Discharge criteria from the PACU, based on a standard Aldrete score modified for pediatric patients [12], were used. CHEOPS was used to assess severity of pain among participants on admission to PACU and repeated on 15 min interval till the discharge out of the PACU.

1.3. Statistical analysis

Sample size was calculated before the study based on alpha error of 0.05 and beta error of 0.1 to detect 25% differences in extubation time between the two groups and it was found to be 17 patients in each group. Data were first tested for normality by Klomogorov–Smirnov test. Normally distributed continuous data were analyzed by using student *t*-test. Non-normally distributed continuous and ordinal data were analyzed using Mann–Whitey U test. Categorical data were analyzed by Chi-square or Fisher's exact test as appropriate. The results are presented as mean (SD), median (interquartile range), or number of patients as appropriate. A P value < 0.05 was considered statistically significant. Statistical analyses were performed using the SPSS for Windows, version 15 (SPSS Inc., Chicago, IL).

1.4. Outcome measures

The primary outcome measure was the time-to-extubate. Additionally, episodes of hypoventilation whether intraoperative or in the PACU, CHEOPS score, agitation score, total duration of time (minutes) spent in the PACU, and incidence of PONV were also recorded.

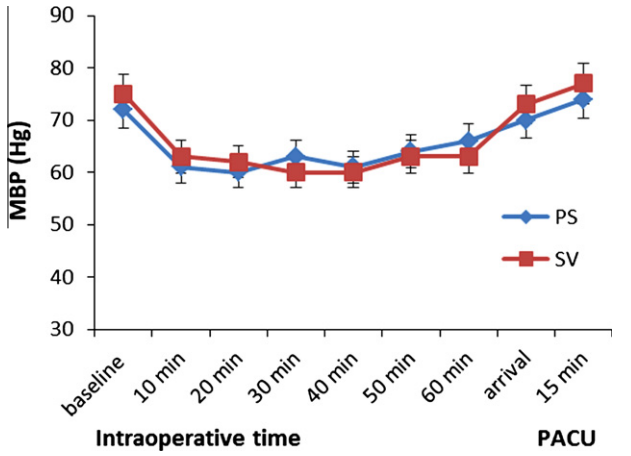

Figure 1 Mean blood pressure (MBP) in mean (SD). PS, pressure support; SV, Spontaneous ventilation; PACU, postanesthesia care unit.

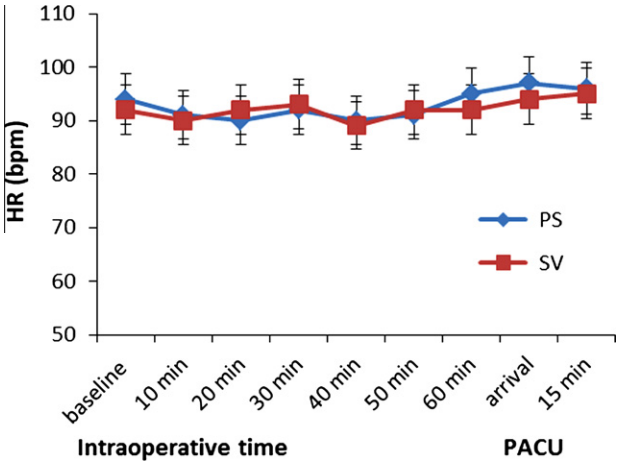

Figure 2 Heart rate (HR) in mean (SD). PS, pressure support; SV, Spontaneous ventilation; PACU, postanesthesia care unit.

2. Results

Patients of the two study groups were comparable in terms of demographic data and surgical details, Table 2, (Figs. 1 and 2). Extubation time (min) [mean (SD)] was significantly longer in SV group than PS group [7.8 (2.1) vs. 5.5 (1.4), $P < 0.001$].

All the patients of the 2 study groups needed intraoperative fentanyl rescue doses other than the dose given after intubation. However, in the PS ventilation group, the total intraoperative dose [mean (SD)] based on mcg/kg was significantly higher compared to the SV group [2.4 (0.5) vs. 2.1 (0.3), $P = 0.04$]. On the other hand, nine patients in the SV group had episodes of hypoventilation that necessitated manual assist of ventilation compared to none in the PS group [$P < 0.001$]. Along the intraoperative course, patients in the PS group needed significantly less inspired volume percent of

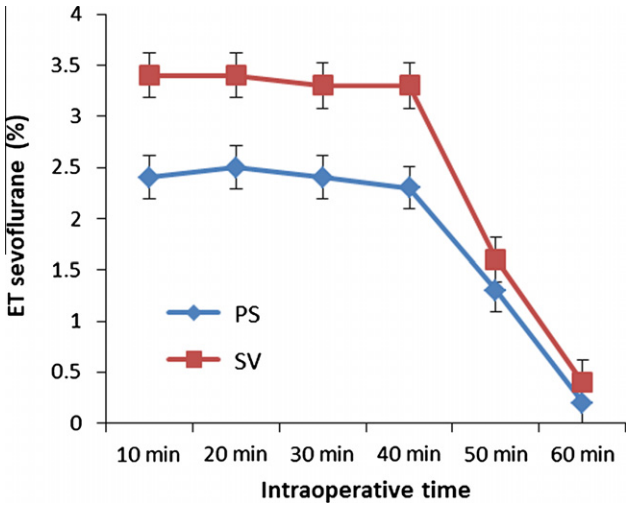

Figure 3 End-tidal sevoflurane concentration is mean (SD). PS, pressure support; SV, Spontaneous ventilation; PACU, postanesthesia care unit; $P < 0.001$.

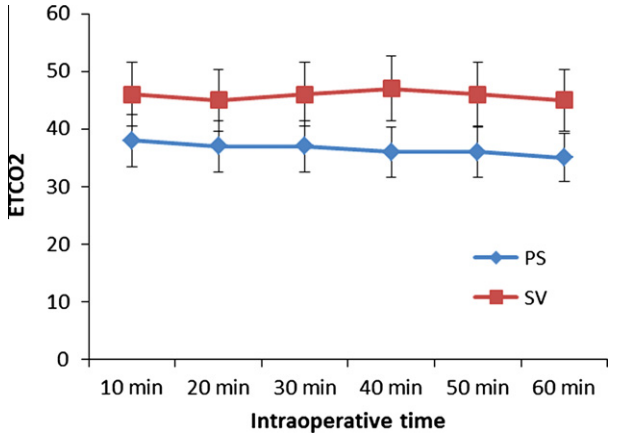

Figure 4 End-tidal carbon dioxide (ETCO2) is mean (SD). PS, pressure support; SV, Spontaneous ventilation; PACU, postanesthesia care unit; $P = 0.003$.

Table 2 Demographic and surgical data. Data are presented as mean (SD) or number as appropriate.

	Group PS ($n = 17$)	Group SV ($n = 17$)
Age (years)	6.5 (2.2)	6 (2.4)
Sex (M/F)	10/7	8/9
Weight (kg)	18.2 (4.3)	17.7 (5.1)
ASA (I/II) (number)	15/2	17/0
Type of surgery (tonsillectomy/ adenotonsillectomy)	4/13	6/11
Surgical time (min)	29 (9.8)	28 (8.7)
Anesthesia time (min)	39.5 (10.5)	44.5 (9.3)

PS, pressure support; SV, spontaneous ventilation.

sevoflurane, compared to those in the SV group, to reach the desired 1.5–2 MAC (Fig. 3). Also, $ETCO_2$ was significantly lower in the former group compared to the latter, (Fig. 4).

Table 3 CHEOPS in median (interquartile range) at different time points in the postanesthesia care unit (PACU).

	Group PS ($n = 17$)	Group SV ($n = 17$)	P value
PACU admission	2 (1)	3 (1.25)	0.004
15 min later	2 (3)	3 (1.25)	0.004
30 min later	2 (2)	3 (1)	0.005
45 min later	2 (2)	3 (1)	0.022
60 min later	2 (1)	3 (1)	0.002

PS, pressure support; SV, spontaneous ventilation; CHEOPS, Children's Hospital of Eastern Ontario Pain Scale.

Table 4 Sedation score in median (interquartile range) at different time points in the postanesthesia care unit (PACU).

	Group PS ($n = 17$)	Group SV ($n = 17$)	P value
PACU admission	2 (1.5)	2 (2)	0.19
15 min later	2 (1)	2 (1.25)	0.27
30 min later	2 (1)	2 (1.25)	0.78
45 min later	2 (1)	2 (1)	0.72
60 min later	2 (1)	2 (1)	0.43

PS, pressure support; SV, spontaneous ventilation.

In PACU, pain scores were significantly higher in SV group than PS group but sedation scores were similar at all-time points, Tables 2 and 3. Six patients in PS group and eight patients in SV group had PONV ($P = 0.45$). Duration of stay in PACU [mean (SD)] in minutes was significantly longer in the SV group than in the PS group [44.3(7.4) vs. 39.4(5.7), $P = 0.02$]. All but one patient in the PS group needed postoperative rescue meperidine analgesia. The mean (SD) time in minutes after which patients needed PACU rescue meperidine analgesia was 27.1(8.9) in PS group and 21.8(9.4) in SV group ($P = 0.04$) Table 4.

3. Discussion

In the current study, PS ventilation as a mode of ventilation for patients undergoing adeno/tonsillectomy had shorter time-to-extubation, lower CHEOPS scores, as well as shorter transit time in the PACU compared to those who breathed spontaneously.

In our study, SV resulted in longer extubation time compared to PS ventilation. Those are the patients who suffered episodes of hypoventilation severe enough to mandate manual assist of ventilation. This, in part, might be attributed to the finding that they needed more inspired volume percent of sevoflurane than did their counterparts in the PS group to reach the desired 1.5–2 expired MAC. Consequently, It might be assumed that because of the dose dependent effect of sevoflurane on minute ventilation [4], patient in the SV group spent more time to wash-out the *"more"* sevoflurane they inspired during anesthesia while they were "less" ventilating.

Lower $ETCO_2$ in the PS group compared to the SV group was achieved when PS was tailored to deliver 8 ml/kg body weight as a tidal volume, (Fig. 4). In the same context, Bosek et al. [6] studied 20 intubated adult patients and reported

reductions in respiratory rate, minute volume, dead space ventilation, and $PaCO_2$ and an increase in pH when PS was titrated (17 ± 3 cmH_2O) to produce a near normal V_T (8 ml/kg), compared to PS with 5 cm H_2O or spontaneous breathing. In another study by Goedecke et al. [7] 20 pediatric, 1–7 yr, surgical patients were managed with Proseal LMA in whom gas exchange improved and work of breathing decreased with PS ventilation.

Patients in both study groups had the same starting intravenous analgesic regimen; paracetamol 15 mg/kg and fentanyl 1 mcg/kg. During the intraoperative course, both drugs failed to maintain HR and MBP below the 20% threshold set to trigger titration of sevoflurane and/or adding a bolus dose of fentanyl. Restoration of HR and MBP was achieved in the SV group with more sevoflurane and less fentanyl compared to the PS group. The combined effects of sevoflurane and fentanyl, in the absence of mechanical assist, could be blamed for the episodes of hypoventilation encountered in the SV group. In a study by Alhashemi and Daghistani [13] of 80 adenotonsillectomy patients, iv fentanyl 1 mcg/kg and acetaminophen 15 mg/kg relieved pain less than when acetaminophen was substituted with i.m. meperidine 1 mg/kg. No intraoperative additional narcotics were needed in their study presumably as they freely titrated sevoflurane to maintain hemodynamic stability added to the analgesic effect of inhaled nitrous oxide.

Though patients in the PS group significantly scored less pain on the CHEOPS compared to patients in the SV group, still all but one patient in the PS group needed rescue meperidine analgesia in the PACU. Similarly, Alhashemi and Daghistani [13] reported the need of opioid rescue analgesia when patient had fentanyl and acetaminophen alone as the intraoperative analgesia. It is worth noticing that patients in the current study received almost double the fentanyl dose given by Alhashemi and Daghistani. The time span from PACU admission to rescue analgesia was significantly longer in the PS group. This might be a result of the higher intraoperative dose of fentanyl they received. Perhaps higher concentrations of sevoflurane in SV decreased their need for opioids. Still, the clinical impact on fentanyl requirements needs further assessment.

Patients were comparable regarding their sedation score at all-time points during their PACU stay. Apart from the mode of ventilation, all patients received the same premedication, intraoperative, and postoperative drugs. In a meta-analysis by Dahmani et al. [14], preoperative fentanyl and pain relief appeared to be effective in preventing emergence agitation, while preoperative midazolam did not.

4. Conclusion

In the current study, PS ventilation as a mode of ventilation for patients undergoing adeno/tonsillectomy resulted in shorter extubation time, lower CHEOPS, as well as shorter transit time in the PACU.

4.1. Limitation of the study

The effect of PS ventilation on gas exchange in the adeno/tonsillectomy patient population was not studied. We thought that arterial cannulation of these children is very invasive for the procedure. Another limitation of the current study is the overlap of sedation and pain relief in pediatrics. To the authors' opinion, it is still hard to differentiate the pain free child from the over sedated one.

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