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Tracheal Extubation in Children: Halothane versus *Isoflurane, Anesthetized* versus *Awake*

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The authors compared the incidence of respiratory complications and arterial hemoglobin desaturation during emergence from anesthesia in children whose tracheas were extubated while they were anesthetized or after they were awake and to whom halothane or isoflurane had been administered. One hundred children 1–4 yr of age undergoing minor urologic surgery were studied. After a standard induction technique, patients were randomized to receive either isoflurane or halothane. In 50 patients tracheal extubation was performed while they were breathing 2 MAC of either halothane or isoflurane in 100% oxygen. The remaining 50 patients received 2 MAC (volatile agent plus nitrous oxide) during the operation, but tracheal extubation was delayed until they were awake. A blinded observer recorded the incidence of respiratory complications and continuously measured hemoglobin saturation for 15 min after extubation. When tracheal extubation occurred in deeply anesthetized patients, no differences were found between the two volatile agents. When tracheal extubation of awake patients was performed, the use of isoflurane was associated with more episodes of coughing and airway obstruction than was halothane ($P < 0.05$). Awake tracheal extubation following either agent was associated with significantly more episodes of hemoglobin desaturation than was tracheal extubation while anesthetized. (Key words: Anesthesia, pediatric. Anesthetics, volatile: halothane; isoflurane. Complications, anesthetic techniques: tracheal extubation.)

RESPIRATORY COMPLICATIONS during and after general anesthesia are a significant potential cause of morbidity and mortality. This is particularly so in children, in whom a high ratio of minute ventilation to functional residual capacity, coupled with a high oxygen consumption, rapidly leads to hypoxemia.[1]

When the incidence of respiratory complications is compared during the induction of anesthesia with halothane or isoflurane, the latter agent is associated with a higher incidence of coughing, breath-holding, airway obstruction, and arterial hemoglobin desaturation.[2–5] There have been no detailed studies comparing halothane and isoflurane with respect to the incidence of complications during emergence from anesthesia. We performed a prospective, randomized, and observer-blinded comparison of respiratory complications associated with these two volatile agents during emergence from anesthesia, after tracheal extubation with the patients still anesthetized, or after they had awakened.

Materials and Methods

With approval of the institutional research review committee, and with informed parental consent, 100 ASA physical status 1 patients, aged 1–4 yr and undergoing minor urologic surgery or abdominal herniotomy, were studied. Patients with an abnormal airway, gastroesophageal reflux, or a history of a respiratory tract infection in the preceding 4 weeks were excluded. Intravenous induction with sodium thiopental 5 $mg \cdot kg^{-1}$ and atropine 0.02 $mg \cdot kg^{-1}$ was followed by succinylcholine 1.5 $mg \cdot kg^{-1}$ to facilitate tracheal intubation. Anesthesia was maintained with nitrous oxide:oxygen 67:33 delivered by a Mapleson D circuit with the patient breathing spontaneously. All patients received a regional nerve block (ilioinguinal or caudal) with 0.25% bupivacaine administered prior to surgery, for postoperative analgesia.

In the first phase of the study, 50 patients were randomized to receive either halothane or isoflurane. At the end of the surgical procedure, the patients received the selected volatile agent in oxygen at an inspired concentration of 2 MAC, adjusted for age,[6–8] for 5 min. They were then turned to the lateral position and the trachea extubated. Oxygen was administered by face mask until the anesthesiologist deemed the patient fit for transfer to the postanesthetic recovery room (PARR). An observer, blinded to the agent used, recorded the occurrence of coughing, breath-holding, airway obstruction, and laryngospasm over the 15 min following extubation, and hemoglobin saturation (Sp_{O_2}) was continuously measured on a Nellcor N-10 pulse oximeter with a paper recorder.

In the second phase of the study, another 50 patients were randomized to receive either halothane or isoflurane. The patients received the selected volatile agent at an inspired concentration of 1.3 MAC, adjusted for age,[6–8] in nitrous oxide:oxygen 67:33 for the duration of the case. At the end of the surgical procedure, each patient received 100% oxygen, and the trachea was extubated when the patient was judged by the attending anesthesiologist to be sufficiently awake. Respiratory complications and Sp_{O_2} were recorded as before.

All patients were transferred to the PARR when their

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TABLE 1. Patient Demographics

	Halothane		Isoflurane	
	Anesthetized	Awake	Anesthetized	Awake
Patients (number)	25	25	25	25
Age (months)	28.8 ± 11.2	25.7 ± 10.8	27.8 ± 9.6	26.3 ± 10.3
Weight (kg)	13.7 ± 2.5	12.9 ± 2.9	13.3 ± 2.2	13.1 ± 1.8
Duration of operation (min)	38.4 ± 15.6	36.2 ± 12.7	35.6 ± 15.0	45.6 ± 16.3*

* Significantly different from all the other groups at $P < 0.05$.

condition was stable, and there they received supplemental oxygen by face mask until they were awake and alert.

Age, weight and duration of anesthesia were compared using the unpaired Student's *t* test with Bonferroni's correction. Frequency of complications and incidence of critical desaturation (defined as an Sp_{O_2} of less than 90 mmHg at any time) were compared using Fisher's exact test. Lowest Sp_{O_2} was compared using the Mann-Whitney U test. *P* values of less than 0.05 were considered statistically significant.

Results

There were 25 patients in each of the four groups (table 1). There were no statistically significant differences between the four groups with respect to age or weight. Compared to all other groups the duration of anesthesia was significantly longer in the patients who received isoflurane and whose tracheal extubation occurred after they were awake. However, in this group, no correlation could be found between the duration of the anesthetic and the occurrence of respiratory complications, and hence the groups were considered comparable.

The incidence of complications is presented in table 2. When patients whose tracheas were extubated while they were deeply anesthetized were compared, no significant differences were found between children anesthetized with halothane and those anesthetized with isoflurane, in either the incidence of respiratory complications or in the lowest Sp_{O_2} recorded (97.1 ± 1.9 *vs.* 96.5 ± 2.1 mmHg, respectively). Ten patients receiving halothane and 12 patients receiving isoflurane had at least one respiratory complication. No patient in whom tracheal extubation was performed during deep anesthesia experienced an Sp_{O_2} of <90 mmHg.

When patients in whom the trachea was extubated after awakening were compared, those anesthetized with isoflurane had a significantly higher incidence of coughing (18 *vs.* 7) and airway obstruction (9 *vs.* 2), and the total number of patients experiencing any respiratory complication was greater (20 *vs.* 10), than in those anesthetized with halothane. There were, however, no significant differences between patients anesthetized with isoflurane and those with halothane in the incidence of Sp_{O_2} <90 mmHg or the lowest Sp_{O_2} recorded (87.4 ± 11.2 *vs.* 89.0 ± 11.2, mmHg respectively).

When all of the patients anesthetized with halothane were examined, there were significant differences found between deeply anesthetized and awake tracheal extubation in the incidence of Sp_{O_2} <90 (0 *vs.* 6) and the lowest recorded Sp_{O_2} (97.1 ± 1.9 deeply anesthetized *vs.* 89.0 ± 11.2 mmHg awake). When all of the patients anesthetized with isoflurane were examined, those undergoing awake tracheal extubation had significantly more coughing (18 *vs.* 1), a higher incidence of at least one respiratory complication (20 *vs.* 12), and of Sp_{O_2} <90 mmHg (11 *vs.*

TABLE 2. Incidence (and Percent Incidence) of Complications and Sp_{O_2} Levels after Extubation

	Halothane		Isoflurane	
	Anesthetized	Awake	Anesthetized	Awake
Coughing	3 (12)	7 (28)†	1 (4)*	18 (72)*·†
Breath-holding	5 (20)	3 (12)	7 (28)	8 (32)
Airway obstruction	5 (20)	2 (8)*	7 (28)	9 (36)*
Laryngospasm	0	1 (4)	1 (4)	3 (12)
Any complication	10 (40)	10 (40)†	12 (48)*	20 (80)*·†
Sp_{O_2} < 90	0†	6 (24)†	0*	11 (44)*
Lowest saturation level recorded (mean ± SD)	97.1 ± 1.9†	89.0 ± 11.2†	96.5 ± 2.1*	87.4 ± 11.2*

*·† Pairs of events that are significantly different at $P < 0.05$.

0) than did those undergoing extubation while anesthetized. There was also a significant difference in lowest Sp_{O_2} (96.5 ± 2.1 deeply anesthetized *vs.* 87.4 ± 11.2 mmHg awake) in the isoflurane-anesthetized patients.

Discussion

Our studies suggest that tracheal extubation while awake compared with extubation while anesthetized was followed by significantly more episodes of Sp_{O_2} <90 with both agents, and by a lower mean lowest recorded Sp_{O_2}. If tracheal extubation of children with normal airways is performed while they are deeply anesthetized with halothane or isoflurane, there does not appear to be any significant difference between the two agents in the incidence of respiratory complications. If tracheal extubation occurs after the children are awake, those anesthetized with isoflurane have significantly more episodes of coughing and airway obstruction than do those anesthetized with halothane.

Patel *et al.*[9] compared deep and awake tracheal extubation in children anesthetized with halothane. They found higher Sp_{O_2} at 1, 2, 3, and 5 min after extubation in patients extubated while deeply anesthetized. However, the incidence of $Sp_{O_2} \leq 90\%$ was the same in patients after awake tracheal extubation or tracheal extubation while anesthetized. Their patients included an unspecified number who were undergoing tonsillectomy and/or adenoidectomy. In addition, the patients in the study by Patel *et al.* had a variety of induction techniques (inhalation, intravenous, intubation with or without muscle relaxant drugs). Our patient selection and anesthetic technique was more rigidly controlled to ensure that our groups were comparable. One potential flaw in our study was the significant difference in the duration of anesthesia of those patients anesthetized with isoflurane and extubated when awake. A few patients in this group had surgical procedures that lasted longer, and this influenced the average duration of surgery of this group. We were, however, unable to detect any correlation within this group between the duration of the anesthetic and the occurrence of respiratory complications of hemoglobin desaturation. Hence, we conclude that it is acceptable to use this group for comparisons.

Although we have demonstrated that airway complications are less frequent, these data should not be interpreted to mean that the tracheas of all children should be extubated while they are deeply anesthetized. There are many patients, such as those with a full stomach or those whose airway is difficult to manage, who should be awake prior to extubation. However, when no specific indication exists for awake tracheal extubation, other considerations may be applied. In such circumstances, tracheal extubation while anesthetized may offer smoother emergence. If it is desirable to extubate the trachea of a patient awake, our data suggest that the use of halothane may offer a smoother emergence than isoflurane.

In summary, the results of our study indicate that in children 1–4 yr of age with normal airways undergoing minor surgery not involving the airway, awake tracheal extubation after either halothane or isoflurane is associated with a greater likelihood of Sp_{O_2} <90 mmHg than is tracheal extubation while deeply anesthetized. The use of isoflurane is associated with more coughing and airway obstruction than is the use of halothane in children who are awake when the trachea is extubated. If the trachea is extubated while the children are deeply anesthetized, there is no difference between the two agents in the incidence of Sp_{O_2} <90 mmHg or of respiratory complications.

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