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Recovery Characteristics of Desflurane Versus Halothane for Maintenance of Anesthesia in Pediatric Ambulatory Patients

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Background: Desflurane is a new potent, inhaled anesthetic agent with low blood–gas solubility that should allow for the rapid induction of and emergence from anesthesia. However, its extreme pungency makes desflurane unacceptable for induction of anesthesia in children. This study was undertaken to determine the airway properties of desflurane administered by mask after anesthetic induction with halothane and nitrous oxide, and to compare the emergence and recovery properties of minimum alveolar concentration (MAC)-equivalent concentrations of desflurane or halothane in nitrous oxide in pediatric patients undergoing ambulatory surgery.

Methods: Forty-five children undergoing ambulatory surgery for inguinal hernia repair, orchiopexy, and/or circumcision were randomized into two groups. Both groups were premedicated with intranasal midazolam and given halothane and nitrous oxide by mask to induce anesthesia. A caudal block was placed in children in both groups after anesthetic induction. For maintenance of anesthesia, group I patients (n = 22) were *switched over to* desflurane (1 MAC) and nitrous oxide, and group II patients (n = 23) continued to receive halothane (1 MAC) and nitrous oxide. All patients breathed spontaneously throughout the entire procedure, and all anesthetics were terminated abruptly at the conclusion of surgery. Recovery indicators (time to first response, length of time in the recovery room and length of time in the hospital) and the quality of the anesthetic emergence were assessed by a nurse blinded to each patient's anesthetic. This observer was present with the patient throughout his or her ambulatory hospitalization and continuously assessed the recovery indicators according to preset criteria.

Results: The groups did not differ with respect to age, weight, or dose of midazolam. Although group I (desflurane) had a longer anesthesia time (52 ± 12 min *vs.* 42 ± 10 min), their time to first response (9.5 ± 6.8 min *vs.* 20.9 ± 14.7 min) and their recovery room time (21 ± 10.7 min *vs.* 29 ± 14.6 min) were less than those in group II (halothane). There was a trend for patient emergence from desflurane anesthesia to be associated with a higher incidence of emergence delirium (50% *vs.* 21%). The two groups were similar with respect to overall duration of postoperative ambulatory hospitalization.

Conclusions: In children premedicated with intranasal midazolam, desflurane maintenance anesthesia allows for a faster recovery. However, depending on the institution's criteria for ambulatory surgical patient discharge, desflurane may or may not affect the overall hospitalization time. (Key words: Anesthesia: pediatrics. Anesthesia techniques: inhalation. Anesthetics, volatile: desflurane; halothane.)

AS the practice of outpatient surgery advances, the search continues for anesthetic agents that provide rapid, smooth induction, intraoperative analgesia and amnesia, rapid emergence, a short postoperative recovery period, and minimal side effects. Desflurane, a new potent, inhaled anesthetic with a blood–gas solubility similar to that of nitrous oxide (N_2O), theoretically could provide these ideal anesthetic qualities. Although the pharmacologic characteristics of desflurane have been described in both adult volunteers and adult surgical patients,[1–10] less information is available on its anesthetic properties in children.[11–14] However, in previously published pediatric studies,[11,12] the pungency of desflurane resulted in unacceptably high incidences of laryngospasm, coughing, and hypoxemia. Consequently, it was concluded that desflurane is not an appropriate induction agent in children. At present, there is no information on the airway properties of desflurane in children when desflurane is administered by mask as a maintenance anesthetic agent, or on the recovery and emergence characteristics of desflurane in pediatric ambulatory patients. This study was undertaken to determine the airway properties of desflurane after anesthetic induction with halothane and nitrous oxide, and to compare the emergence and recovery properties of minimum alveolar concentration (MAC)-equivalent concentrations of desflurane and halothane

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in nitrous oxide in pediatric patients undergoing ambulatory surgery.

Materials and Methods

Forty-five patients scheduled to undergo outpatient surgery for inguinal hernia repair, orchiopexy, and/or circumcision were randomized into two groups by use of a computer-generated table. All patients were premedicated with intranasal midazolam (0.2–0.3 mg/kg). In all patients, anesthesia was induced by mask with halothane in a 60:40 nitrous oxide and oxygen mixture using a Mapleson D circuit. After the patients had lost consciousness and was spontaneously breathing 1.0 MAC of halothane, an intravenous catheter was inserted, and a caudal block (0.25% bupivacaine 1 ml/kg) was performed. After placement of the caudal block, patients in group I (n = 22) were switched to desflurane in a 60:40 nitrous oxide and oxygen mixture, whereas patients in group II (n = 23) continued to receive halothane, nitrous oxide, and oxygen. Desflurane was vaporized using the Ohmeda Tec 6 vaporizer (West Yorkshire, UK). All patients continued to breathe spontaneously by mask through a Mapleson D circuit throughout the procedure. End-tidal halothane and desflurane concentrations were maintained at 1.0 MAC.[14,15] Arterial blood pressure, heart rate, end-tidal carbon dioxide, end-tidal anesthetic gases, and hemoglobin oxygen saturation (SpO_2) were measured continuously. End-tidal carbon dioxide and end-tidal inhaled anesthetic gas concentrations were measured with the Datex Ultima capnograph (Helsinki, Finland). End-tidal carbon dioxide and anesthetic gas concentrations were sampled from the tip of the catheter inside the Mapleson D circuit that traversed an oral airway and was in the oropharynx.

Administration of all inhaled anesthetic agents was terminated at the end of surgery. Signs and symptoms of airway irritability (laryngospasm, coughing) during the maintenance and emergence periods of anesthesia were recorded by an investigator who was not blinded to the anesthetic agents. The times from cessation of the anesthetic until the patient first responded (opened eyes or made purposeful movements) and met specified criteria for discharge from the recovery room and the hospital were recorded by a nurse observer blinded to the anesthetic assignment. Our institution has a two-stage recovery area. The first stage is in the postanesthesia care unit (PACU). Once a patient meets the criteria for discharge from the PACU, the second stage of recovery occurs in the ambulatory surgical unit, which is physically separate from the PACU. The criterion for discharge from the PACU was a score of ≥ 8 on our institution's 10-point PACU score (table 1).

The criteria for hospital discharge were discharge from the PACU and the ability of the child to drink fluids once in the ambulatory unit. The study nurse continuously observed each patient in the PACU and ambulatory unit. She also characterized the quality of the recovery from anesthesia, recorded the incidence of emesis in the PACU and ambulatory units, and telephoned a parent 24 h later to discern the incidence of emesis at home and the overall quality of the patient and family's surgical experience. The incidence of emergence delirium was based on the quality of the anesthesia recovery. The anesthesia recovery was assessed on a three-point scale: 1 = asleep or calm; 2 = mildly agitated, crying but consolable, restless; and 3 = hysterical, crying inconsolably, and thrashing. Patients with an emergence score of 3 were defined as delirious, whereas patients with a score of 1 or 2 were thought to have a calm or smooth emergence. Postoperative pain was managed with the caudal block placed intraoperatively and oral acetominophen. If further analgesia was required, fentanyl was administered intravenously.

Statistical comparisons involving continuous variables were performed with a two-tailed, unpaired *t* test. Data involving incidence of emergence delirium and

Table 1. Post Anesthesia Care Unit Assessment and Recovery Score

Respiration
Apneic = 0
Dyspnea or limited breathing = 1
Able to breathe deeply and cough freely = 2
Activity
Able to move no extremities voluntarily or on command = 0
Able to move two extremities voluntarily or on command = 1
Able to move four extremities voluntarily or on command = 2
Consciousness
Nonresponsive = 0
Responding to stimuli = 1
Awake = 2
Circulation, preoperative blood pressure (BP)
BP >120% of preanesthetic level = 0
BP >111% <120% of preanesthetic level = 1
BP ≤110% of preanesthetic level = 2
Temperature
Axillary temperature <35° C or >37.5° C = 0
Axillary temperature between 35° C and 35.5° C = 1
Axillary temperature 35.6–37.5° C = 2

Table 2. Patient Demographics

	n	Age (months)	Weight (kg)	Dose of Midazolam (mg/kg)	Time from Preanesthesia Medication to Induction of Anesthesia (min)	Time from Preanesthesia Medication to End of Surgery (min)
Desflurane	22	37.8 ± 26.4	15.2 ± 5.1	0.25 ± .07	34 ± 15	86 ± 19
Halothane	23	30.4 ± 15.4	14.7 ± 4.4	0.25 ± .06	34 ± 13	76 ± 14

Data are mean ± SD.

postoperative emesis were analyzed by chi-square and Yate's continuity correction. Statistical significance was considered at $P < 0.05$. Before the start of the study, a power analysis suggested that 20 patients per group was sufficient to detect a 40% change in the awake times (power 80%, α 0.05).

Results

There was no statistically significant difference between the groups with respect to age, weight, the times from the administration of premedication to the induction of anesthesia, the time from the administration of premedication to the end of surgery, or the dose of preanesthetic medication (table 2). The patients anesthetized with desflurane had a longer mean anesthesia time, a shorter time to first response, and a shorter recovery-room time than did the patients who received halothane (table 3). There was a trend in patients receiving desflurane anesthesia to have a higher incidence of delirium on emergence ($P = 0.09$). However, there was no statistical difference in either the hospitalization discharge times or airway complications between the two groups, or in the overall incidence of postoperative nausea and vomiting in the recovery room, the ambulatory unit, or at home during the first 24 h (3 of 22 *vs.* 3 of 23; table 3). In the postoperative recovery area, three patients in the desflurane group required fentanyl, compared with one patient in the halothane group (not significant).

Discussion

This study was undertaken to compare the anesthetic properties of desflurane and halothane in the clinical setting commonly used for pediatric ambulatory surgery. Ideal anesthetic agents for outpatient anesthesia should provide rapid, smooth induction and emergence, amnesia, analgesia, and hemodynamic stability. Desflurane, with its low blood–gas solubility, should offer these conditions. However, induction with desflurane in children has been associated with significant incidences of coughing, apnea, and laryngospasm.[11,12] These side effects delay the onset of induction and limit the use of this anesthetic agent in pediatric patients. Because of desflurane's unsatisfactory performance as a pediatric induction agent, its potential benefit would be evident during anesthetic maintenance and emergence.

Our study design, incorporating intraoperative nerve blocks in all patients and a blinded nurse observer who made continuous patient assessments, had significant advantages in characterizing the wake-up and recovery of pediatric ambulatory surgical patients after anesthesia. The use of intraoperative caudal blocks allowed the patients to be pain-free during emergence and re-

Table 3. Patient Recovery and Emergence Characteristics

	Duration of Anesthesia (min)	Time until First Response (min)	Time to PACU Discharge (min)	Time until Hospital Discharge (min)	Incidence of Delirium* (n; %)	Incidence of Nausea and Vomiting (n; %)	Airway Complications (n; %)
Desflurane	52 ± 12†	9.5 ± 6.8†	21 ± 10.7†	76 ± 33	11; 50	3; 13.6	0; 0
Halothane	42 ± 10	20.9 ± 14.7	29 ± 14.6	68 ± 33	5; 21	3; 13.0	1; 4.3

Data are mean ± SD.

PACU = post anesthesia care unit.

* $P = 0.09$.

† $P < 0.05$.

covery and obviated the need for postoperative narcotics. Consequently, the emergence and recovery from anesthesia were not influenced by pain or the side effects of opioids. The presence of a blinded nurse observer who had no other clinical responsibilities and who could evaluate patient readiness continually provided an accurate assessment of the time at which patients were ready to leave the recovery room and hospital.

Our emergence and recovery findings in children anesthetized with desflurane or halothane are similar to the findings reported in comparable adult studies in which patients were anesthetized with desflurane, isoflurane, or propofol. In adults, Van Hemelrijck *et al.*[16] compared ambulatory surgical patients randomized into one of four groups: (1) propofol induction with propofol and nitrous oxide maintenance, (2) propofol induction with desflurane and nitrous oxide maintenance, (3) desflurane and nitrous oxide for both induction and maintenance, or (4) desflurane for induction and maintenance. Although emergence from anesthesia as assessed by appropriate responses to verbal commands occurred sooner in adults anesthetized with desflurane and oxygen, the times from arrival in the recovery room to sitting, standing, walking, tolerating oral fluids, and being judged street-ready were similar for all four groups.

Ghouri *et al.*[6] administered MAC-equivalent concentrations of desflurane and isoflurane in a nitrous oxide and oxygen mixture and observed that the patients anesthetized with desflurane were alert earlier and had less cognitive impairment than the patients anesthetized with isoflurane. However, psychometric measures and discharge times from the ambulatory surgical center were the same for both groups.[6]

Fletcher *et al.*,[17] using psychomotor performance tests (choice reaction time and critical flicker fusion thresholds) in ambulatory surgical patients, noted that desflurane was associated with a more rapid patient awakening and less impairment on the choice reaction time test. Tsai *et al.*,[18] using simpler psychomotor performance tests (*i.e.*, Trieger Dot tests, digit substitution test, and verbal responses to mental status questions), noted findings similar to those of Fletcher *et al.* Patients anesthetized with desflurane awakened more rapidly from anesthesia and returned more quickly to cognitive function than did the patients anesthetized with isoflurane.[18] However, in the studies of Fletcher *et al.*,[17,18] the designs precluded determining the exact times to hospital discharge.

Why ambulatory patients who become alert faster are not discharged from the hospital sooner remains unanswered. Part of the explanation in our study may be a matter of definition of the criteria for hospital discharge. In our institution, the taking and retaining of oral fluids is a criterion for discharge from the ambulatory surgical unit. Recently, Schreiner *et al.* showed that the requirement of taking and retaining oral fluids unnecessarily prolongs hospital discharge after ambulatory pediatric surgery.[19] Therefore, criteria used for discharging patients from the hospital can influence the length of stay after anesthesia. If oral fluids were not part of hospital discharge criteria, then the patients anesthetized with desflurane would have been judged street-ready sooner and, consequently, discharged from the hospital sooner than the patients anesthetized with halothane. In the adult studies, the times at which patients were street-ready were assessed by nurses according to their normal nursing routine. Consequently, bias may have been a factor, *i.e.*, patients may have been judged street-ready based on how long they had been in the ambulatory unit after surgery rather than by discharge criteria.

In our study, children anesthetized with desflurane appeared to respond earlier than the children anesthetized with halothane; however, 50% of them had postanesthetic delirium (*i.e.*, thrashing and inconsolable crying) compared with 21% of patients anesthetized with halothane. Although this did not reach statistical significance ($P = 0.09$), our small sample size may preclude finding a difference. This trend in stormy emergences or delirium on emergence appears to be different from findings in adults. Tsai *et al.*[18] reported no delirium in a group of healthy adults anesthetized with desflurane but found a 44% incidence in patients who received isoflurane. They commented that the rapid transition from anesthesia to consciousness may explain the absence of observed delirium.[18] In children, however, this rapid transition from anesthesia to consciousness actually may promote delirium. The rapid return to consciousness in a strange area with strangers taking care of the child may exacerbate a child's underlying sense of apprehension and fear. These factors, compounded by concerns regarding bodily injury, may be manifested during emergence from anesthesia. However, studies with larger patient numbers will be needed to further assess the emergence characteristics of desflurane in children.

Of interest was the lack of airway irritability observed during the maintenance and emergence periods with mask-administered desflurane. This absence of airway problems is similar to the findings reported by Taylor and Lerman in children in whom the trachea was intubated,[12] but contrasts markedly with the airway irritability observed when desflurane is used as an induction agent.[9,11,12] Why the airway properties should be different on induction and emergence remains unclear. With respect to postoperative nausea and vomiting, there appears to be no difference between patients anesthetized with halothane or desflurane in the PACU, the ambulatory surgical area, and at home. Although earlier results with desflurane in a pediatric multicenter study suggested that desflurane may have antiemetic properties, our data do not support this finding.[11]

In summary, if a crossover technique is used (halothane induction, desflurane maintenance), desflurane can be administered by mask to pediatric patients. During emergence, desflurane is not associated with increased airway complications. In ambulatory surgical patients medicated with nasal midazolam, desflurane (compared with halothane) is associated with a faster emergence and recovery from anesthesia. The faster recovery from desflurane allows for a shorter PACU stay. However, depending on the institution's guidelines for hospital discharge, desflurane can affect hospital length of stay for the pediatric ambulatory surgical patient.

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