Emergence and Recovery Characteristics of Desflurane Versus Sevoflurane in Morbidly Obese Adult Surgical Patients: A Prospective, Randomized Study

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We compared postoperative recovery after desflurane ($n = 25$) versus sevoflurane ($n = 25$) anesthesia in morbidly obese adults (body mass index ≥35) who underwent gastrointestinal bypass surgery via an open laparotomy. After premedication with midazolam and metoclopramide 1 h before surgery, epidural catheter placement, induction of anesthesia with fentanyl and propofol, and tracheal intubation facilitated with succinylcholine, anesthesia was maintained with age-adjusted 1 minimum alveolar concentration (MAC) desflurane or sevoflurane. Fentanyl IV, morphine or local anesthetics epidurally, and vasoactive drugs as needed were used to maintain arterial blood pressure at ±20% of baseline value and to keep bispectral index of the electroencephalogram values between 40 to 60 U. Although patients were anesthetized with desflurane for a longer time (261 ± 50 min versus 234 ± 37 min, mean ± SD; $P < 0.05$, desflurane versus sevoflurane, respectively) and for more MAC-hours (4.2 ± 0.9 h versus 3.7 ± 0.8 h; $P < 0.05$), significantly earlier recovery of response to command and tracheal extubation occurred in patients given desflurane than in patients given sevoflurane. The modified Aldrete score was greater in desflurane-anesthetized patients on admission to the postanesthesia care unit (PACU) ($P = 0.01$) but not at discharge ($P = 0.47$). On admission to PACU, patients given desflurane had higher oxygen saturations (97.0% ± 2.4%) than patients given sevoflurane (94.8% ± 4.4%, $P = 0.035$). Overall, the incidence of postoperative nausea and vomiting and the use of antiemetics did not differ between the two anesthetic groups. We conclude that morbidly obese adult patients who underwent major abdominal surgery in a prospective, randomized study awoke significantly faster after desflurane than after sevoflurane anesthesia and the patients anesthetized with desflurane had higher oxygen saturation on entry to the PACU.

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Favorable emergence and recovery profiles of newer volatile anesthetics have made their use increasingly common. Studies in healthy volunteers indicate that recovery from anesthesia proceeds nearly twice as fast with desflurane as with sevoflurane (1,2). Differences in blood/gas and tissue/blood solubility coefficients of these drugs account for this observation (3–6).

All volatile anesthetics accumulate, over time, in adipose tissue. Such accumulation may delay recovery from anesthesia. The impact of anesthetic stored in fat may be the result of a return of the anesthetic in blood perfusing the fat or of a transfer from fat to adjacent highly perfused tissues (e.g., omental/mesenteric fat to intestine and liver) (7). The effect of these factors might be exaggerated in morbidly obese patients, particularly after prolonged anesthesia. Emergence from desflurane versus sevoflurane has not been studied in morbidly obese patients, although Juvin et al. (8) have shown that recovery is more rapid in such patients when they are anesthetized with desflurane versus isoflurane. The present study sought to determine if awakening and recovery times differed between desflurane and sevoflurane anesthesia in morbidly obese patients. The hypothesis was that emergence and recovery would be faster after desflurane than after sevoflurane anesthesia.

Methods

Our local IRB approved this study and all patients gave informed written consent. We studied 50 morbidly obese patients (body mass index ≥35 kg/m^2 and

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ASA physical status II–III) requiring gastrointestinal bypass surgery via open laparotomy. The same surgeon operated on 44 (88%) of the patients. Patients were randomized to receive either desflurane ($n = 25$) or sevoflurane ($n = 25$) for maintenance of anesthesia. Excluded from the study were patients 1) with ASA physical status >III, 2) with a history of allergy to anesthetic drugs, including volatile anesthetics, 3) potentially susceptible to malignant hyperthermia (personal or family history), 4) with renal or liver disease, 5) with a history of known chronic alcohol or narcotic substance abuse within 90 days of surgery, 6) with a disabling disease of the central nervous system, 7) with severe obstructive or restrictive pulmonary disease, and 8) with use of any investigational drug within the 30 days before surgery or who were scheduled to receive any investigational drug during the course of this study. Criteria for early withdrawal from the study were 1) <2 h surgical time, 2) any surgical or anesthetic complication that prevented the assessment of study variables, 3) clinically relevant residual neuromuscular relaxant effect, or 4) any other reason that necessitated prolonged tracheal intubation after surgery. Six patients were withdrawn from the study: five patients because the trachea remained intubated after surgery (three patients in the desflurane group and two patients in the sevoflurane group), and one patient because of protocol violation (in the sevoflurane group). Data from patients withdrawn early were not used in the analysis.

After premedication with midazolam and metoclopramide and epidural catheter placement, anesthesia was induced with fentanyl and propofol. Tracheal intubation was facilitated with succinylcholine. Positive pressure ventilation was initiated and maintained for the duration of surgery with a tidal volume of 8 to 10 mL/kg and a ventilatory rate adjusted to maintain an end-tidal P_{CO_2} of 30 to 40 mm Hg.

Anesthesia was maintained with age-adjusted 1 minimum alveolar concentration (MAC) target concentrations (9) of desflurane or sevoflurane in oxygen and air for patients given desflurane versus those given sevoflurane ($n = 22$ versus 23, respectively) or in oxygen only for patients given desflurane versus those given sevoflurane ($n = 3$ versus 2). The use of oxygen and air or oxygen only was left to the discretion of the attending anesthesiologist. The only criterion was to not use N_2O. Minimum fresh gas flow was 2 L/min, administered via a circle breathing system with a carbon dioxide absorber. End-tidal concentrations were analyzed with a Datex-Ohmeda Ultima gas analyzer (Datex-Ohmeda, Helsinki, Finland).

IV fluids, additional fentanyl, vecuronium and neostigmine, and glycopyrrolate, antiemetics, and vasoactive drugs were administered at the anesthesiologist's discretion. In addition to ASA standard monitors, intraoperative monitoring included continuous bispectral analysis (BIS Monitor Model A-2000; Aspect Medical Systems, Newton, MA), direct arterial blood pressure, and central venous pressure (CVP).

The continuously monitored hemodynamic and BIS values were recorded before induction of anesthesia (baseline), immediately after tracheal intubation, between induction and skin incision, immediately and at 1, 2, 3, 4, 5, 6, 8, 10, 15, 20, 30, 45, 60, 90, 110, 120 min after skin incision, and then every 15 min until the end of surgery. Intraoperative hemodynamic stability was ensured by adequate volume replacement (controlled by the CVP values, 10–15 cm H_2O), continuous urine output monitoring, systemically administered fentanyl, and/or vasoactive drugs as needed.

The end-tidal concentration of desflurane or sevoflurane was maintained at 1 MAC until the end of surgery. Immediately after the last skin stitch, volatile anesthetic administration was discontinued, without tapering its delivery during the period approaching the end of surgery. We chose this method because we wanted to prevent inconsistent (and potentially biased) tapering times and rates of decreasing the volatile anesthetic concentrations before the end of surgery from influencing emergence times. At the end of surgery, the fresh gas inflow rate was changed to 6 L/min of oxygen and neostigmine and glycopyrrolate were administered to antagonize residual neuromuscular block. The tracheal tube was removed when the patient met our criteria for tracheal extubation (spontaneous breathing with a minimum of 8 mL/kg body weight, ability to sustain a 5-s head lift, an adequate negative inspiratory force [> -40 cm H_2O], sustained hand grip, and sustained arm lift). At 1-min intervals, starting from the time of discontinuation of anesthetic administration, a blinded investigator asked each patient to open his or her eyes, squeeze the investigator's hand, state his or her name, and then give date of birth until correct answers were given.

All patients were discharged from the operating room (OR) to the postanesthesia care unit (PACU) for intermediate recovery and from the PACU to the intensive care unit (ICU) for 24–48 h. Intermediate recovery variables (modified Aldrete score) were measured on arrival in the PACU and then at 15, 30, 45, 60, 90, and 120 min. An investigator, who did not know which anesthetic was given to the patient, evaluated each patient's quality of recovery. The evaluation of intermediate recovery was made by using the objective criteria of modified Aldrete scoring recommendations (9). We scored each variable—consciousness, activity, respiration, circulation, and oxygen saturation—with numbers of 0, 1, or 2, with a maximum achievable score of 10. We totaled the scores given for each variable and compared the differences in scores between patients given desflurane versus those given sevoflurane on arrival to PACU,

and then at 15, 30, 45, 60, 90, 120 min and/or immediately before discharge from the PACU.

On the same time schedule, using a pain visual analog scale (VAS) ranging from 0 (none) to 10 (worst), we asked each patient about pain intensity. Concurrently, we asked each patient to assess the degree of nausea, using a categorical scale of none, mild, moderate, or severe. These observations also were made on arrival to PACU and then at 15, 30, 45, 60, 90, 120 min and/or immediately before discharge from the PACU. Using a blinded observer, we extended the observation of occurrence and treatment for nausea on each patient (except for categorical scaling), as recorded by the nurses in the ICU and hospital wards for every postoperative day, until hospital discharge.

We analyzed our data using the following statistical methods. Student's *t*-tests were applied to parametric data that were not skewed. The remaining tests were applied to skewed or nonparametric data. Two-tailed Student's *t*-test was used for comparison of emergence times between the desflurane and the sevoflurane groups in the OR. Mann-Whitney *U*-test was used for comparison of intraoperatively IV administered fentanyl doses and the length of stay in the PACU. The χ^2 and a Kruskal-Wallis test were used for the analysis of postoperative pain VAS scores in the PACU for the first 120 min. Results were reported as mean ± SD and median (range). A $P < 0.05$ was considered statistically significant.

Results

The two groups were comparable in age, weight, and gender distribution (Table 1). Several variables did not differ between patients given desflurane versus those given sevoflurane. These included BIS or MAC values, duration of surgery or anesthesia, morphine dose, and the length of PACU stay or hospital stay. MAC-hours and exposure time to inhaled anesthetic were significantly longer and the total intraoperative dose of IV administered fentanyl was significantly larger for patients given desflurane versus those given sevoflurane. Because the induction doses of fentanyl did not differ between the desflurane group and the sevoflurane group, patients who were given desflurane received significantly more fentanyl for the maintenance of anesthesia than those given sevoflurane (Table 1). However, when the total dose of fentanyl was adjusted to dose/total time of anesthesia, the significant difference disappeared ($P = 0.10$ after adjustment versus $P < 0.05$ before adjustment).

We placed epidural catheters for 22 patients (17 activated in the OR) or 24 (18 activated in the OR) in the desflurane and sevoflurane groups, respectively. The total dose of epidurally administered drugs during surgery did not differ between the desflurane versus sevoflurane groups: morphine sulfate 3.5 ± 0.9 mg versus 3.1 ± 1.0 mg, ropivacaine 67 ± 22 mg versus 67 ± 46 mg, bupivacaine 67 ± 38 mg versus 50 ± 38 mg, and lidocaine 233 ± 152 mg versus 170 ± 71 mg. The groups did not differ in blood pressure (systolic, diastolic, and mean) or heart rate from 2 minutes after skin incision until the last skin stitch (Fig. 1).

The times from discontinuation of volatile anesthetic administration to eye opening, squeezing hand, tracheal extubation, and orientation were significantly shorter in patients given desflurane than in patients given sevoflurane (Table 2). The time from discontinuing anesthetic administration to PACU admission was 35.8 ± 11.6 min versus 26.3 ± 7.7 min ($P = 0.0015$) for patients given sevoflurane versus desflurane. On admission to the PACU, we found significantly higher oxygen saturations in patients given desflurane (97.0% ± 2.4%) than in patients given sevoflurane (94.8% ± 4.4%, $P = 0.035$). Despite arriving sooner in the PACU, patients given desflurane had significantly higher modified Aldrete scores on arrival to the PACU than patients given sevoflurane (8.1 ± 1.1 versus 7.1 ± 1.5, $P = 0.01$). Aldrete scores significantly improved by discharge and at discharge did not differ between patients given desflurane (8.7 ± 0.8) versus those given sevoflurane (8.5 ± 1.0, $P = 0.47$). Patients given desflurane did not differ from those given sevoflurane in time spent in the PACU nor in time spent in the hospital (Table 1). Variations among pain VAS score medians of desflurane and sevoflurane group were not significantly greater than expected by chance, thus the groups did not differ in pain VAS scores in the PACU for the first 120 min ($P = 0.96$).

Overall, patients given desflurane did not differ from those given sevoflurane in their incidence of postoperative nausea and vomiting. On average, patients given desflurane had more nausea than those given sevoflurane in the PACU but less in the ensuing 24 h. That is, there was no significant difference in postoperative nausea and vomiting for the first day, nor was there a significant difference on ensuing days. The amount of ondansetron given to patients anesthetized with desflurane versus sevoflurane did not differ on the first postoperative day (5.0 ± 5.7 mg/patient for desflurane and 5.9 ± 6.7 mg/patient for sevoflurane) or for the first 5 postoperative days (12.5 ± 15.6 mg/patient for desflurane and 15.5 ± 17.5 mg/patient for sevoflurane).

Discussion

The present study demonstrates that morbidly obese patients anesthetized for more than 3 hours recover significantly more rapidly after desflurane anesthesia than after sevoflurane anesthesia. The time to first appropriate response to command, orientation, and

Table 1. Demographic and Operative Data

Variables	Desflurane (n = 25)	Sevoflurane (n = 25)	P value
Age (yr)	41.4 ± 9.6 (30–63)	42.9 ± 9.7 (30–64)	NS
Gender (males/females)	6/19	4/21	
Weight (kg)	155 ± 34 (103–218)	152 ± 36 (97–255)	NS
Height (cm)	170 ± 9 (155–185)	168 ± 9 (152–191)	NS
Body Mass Index (kg/m^2)	53 ± 111 (38–81)	54 ± 10 (38–80)	NS
Duration of surgery (min)	206 ± 40 (144–306)	186 ± 38 (120–265)	NS
Duration of anesthesia (min)	275 ± 49 (175–365)	258 ± 45 (156–342)	NS
Exposure to inhal. agent (min)	261 ± 50 (175–347)	234 ± 37 (153–314)	<0.05
Ventilation with O_2 + air/only O_2 (n)	22/3	23/2	
ASA PS	2–3	2–3	
MAC	0.96 ± 0.05	0.94 ± 0.09	NS
MAC-hours (h)	4.2 ± 0.9	3.7 ± 0.8 (n = 24)	<0.05
End tidal concentration (%)	5.9 ± 0.6	2.0 ± 0.3	
Bispectral index (Unit)	37 ± 9 (n = 24)	41 ± 6 (n = 24)	NS
Fentanyl IV induction (μg/kg)	0.92 (0.5–2) (n = 23)	1.0 (0.4–2.2) (n = 22)	NS
Fentanyl IV maintenance (μg/kg)	2.1 (1.1–8.3) (n = 23)	1.7 (0.6–3.9) (n = 22)	NS
Propofol IV (mg/kg)	1.4 ± 0.6	1.4 ± 0.4 (n = 24)	NS
Morphine IV (mg)	13.3 ± 6.7 (n = 11)	9.0 ± 5.6 (n = 13)	NS
Vecuronium (μg/kg)	144 ± 0.03 (n = 24)	138 ± 0.05 (n = 22)	NS
Length of PACU stay (min)	162 (84–538) (n = 24)	160 (90–429)	NS
Length of hospital stay (day)	6.7 ± 2.7 (n = 24)	6.5 ± 2.0	NS

Except for gender, ASA PS, number of patients ventilated with air/O_2 or O_2 only, length of postanesthesia care unit (PACU) stay and fentanyl doses, which are given as median (range), data are mean ± SD. Ranges and number of patients, if less than 25, are in parentheses.

Duration of surgery = time from skin incision to the last skin stitch; duration of anesthesia = time from the start of the IV induction to tracheal extubation; MAC = minimum alveolar anesthetic concentration; ASA PS = American Society of Anesthesiologists physical status.

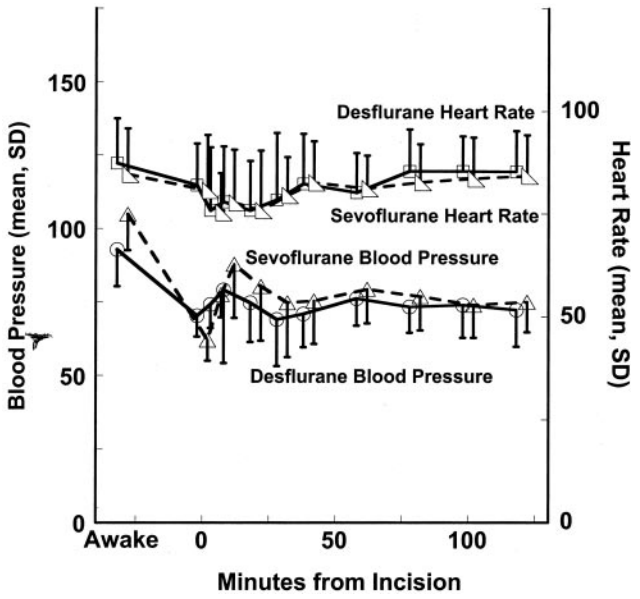

Figure 1. Mean arterial blood pressure and heart rate did not differ either before (awake) or during the course of anesthesia with desflurane versus sevoflurane. Each point presents the mean and SD.

tracheal extubation was approximately half as long after desflurane anesthesia. Patients given desflurane left the OR significantly sooner than those given sevoflurane. After desflurane anesthesia, patients arrived in the PACU with higher modified Aldrete scores and greater oxyhemoglobin saturations than did patients after sevoflurane anesthesia.

Table 2. Emergence and Immediate Recovery Times After Discontinuation of Volatile Anesthetics in the Two Anesthetic Groups

Time to (min)	DES	SEVO	P value (SEVO versus DES)
Eye opening	9.9 ± 4.5	18.5 ± 8.7 (87)	<0.0001
Hand grip	13.8 ± 7.1	22.4 ± 11.5 (62)	<0.004
Tracheal extubation	14.2 ± 8.0	25.5 ± 12.0 (80)	<0.0003
Telling name	18.4 ± 8.4	32.1 ± 13.7 (75)	<0.0001
Telling DOB	20.4 ± 8.8	34.5 ± 14.4 (69)	<0.0003

Values are expressed as mean ± SD (% difference).

DOB = date of birth.

The emergence times of the desflurane (DES) group were significantly less than those of the sevoflurane (SEVO) group.

Our results are consistent with those found by Eger et al. (1,2), who compared recovery characteristics in healthy male volunteers of normal weight. As did we, they found that response to command and orientation took about half the time after desflurane anesthesia than after sevoflurane anesthesia. Psychometric and cognitive functions also recovered faster after desflurane anesthesia.

Numerous other reports indicate that recovery is more rapid with desflurane than with other inhaled anesthetics, including sevoflurane (10–17), whereas a few show no difference in early recovery from anesthesia or in recovery of cognitive function (18,19). Although studies have compared desflurane versus

sevoflurane in other patient populations, none has examined morbidly obese adult surgical patients. Only one other report has compared desflurane to another inhaled anesthetic (in this case, isoflurane) for morbidly obese patients (8). As in the present report, desflurane anesthesia was associated with a more rapid recovery.

The newest volatile anesthetics, desflurane and sevoflurane, have significantly lower blood/gas partition coefficients (0.45 and 0.65, desflurane versus sevoflurane, respectively) than isoflurane (1.4) or halothane (2.4), predicting better intraoperative control of anesthesia and a more rapid recovery from anesthesia (3–6). As noted above, our results are consistent with the prediction that lower solubility produces a more rapid recovery. A more rapid recovery may be associated with earlier maintenance of a patent airway, better protection against aspiration, and better oxygenation (20). Indeed, better oxygenation was found in the present study. Rapid recovery may allow a more rapid return to a preoperative/baseline cardiovascular function and an earlier departure from the OR (21). The resumption of activities requiring coordination may be attained more rapidly, lead to greater safety, and be economically advantageous and desirable from the patient's point of view.

It was not our primary goal to study the discharge eligibility from PACU, as all patients in both groups were discharged from PACU to ICU routinely with the exception of one patient who was discharged from the OR to the ICU directly. Desflurane versus sevoflurane anesthesia did not differ with respect to time to intermediate recovery in PACU.

Overall, no difference was found for the incidence of postoperative nausea or the need for antiemetic medication. When it occurred, nausea appeared to develop sooner in patients given desflurane, perhaps in association with the earlier awakening permitted by desflurane's lower solubility.

A more rapid immediate recovery in morbidly obese patients may confer several benefits. Such patients may be at risk for airway complications, sleep apnea, and hypoxia during the early recovery period (9,21–23). Faster emergence, extubation with a secure airway, and maintenance of spontaneous ventilation might be predicted to benefit recovery and patient comfort. A decreased time spent in the OR and quicker turnover of the OR may decrease cost (24,25). Other approaches to anesthesia (e.g., a tapering of anesthetic administration toward the end of surgery) might decrease the differences in recovery times and, accordingly, decrease cost savings.

In this study, surgery was conducted as an open procedure. This procedure is also being performed with a laparoscopic approach that should allow a much earlier assessment of mentation and return to normal activities because of decreased postoperative discomfort. Laparoscopic surgery would be expected to decrease postoperative pain, lessen the need for intraoperative and postoperative narcotic drug administration, improve oxygenation, and decrease the incidence of postoperative nausea and vomiting, especially during the early postoperative period.

In summary, in morbidly obese patients, using age-adjusted 1 MAC end-tidal concentration, we find that the time to emergence and early recovery from prolonged anesthesia with desflurane is shorter than with sevoflurane anesthesia.

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