This study compared the costs of desflurane and propofol as maintenance anesthetic agents in outpatient surgery. Recovery time and related drug expenses were included in the cost comparison.

Fifty-three ASA physical status I and II patients were randomly assigned to receive a maintenance anesthetic of either desflurane with 50% nitrous oxide or propofol with 50% nitrous oxide. All patients received a propofol induction and were administered narcotics, sedatives, muscle relaxants, reversal agents, and antiemetics as determined necessary by the anesthesia provider.

The mean propofol cost was $31.77 ± 14.44, whereas, the mean desflurane cost was $12.99 ± 7.61 (P < .05). The mean cost of all medications, anesthetics, and ancillary agents included was $57.97 ± 20.22 for the propofol group and $34.86 ± 14.13 for the desflurane group (P < .05). Of the desflurane patients, 41% experienced nausea compared to 12% of the propofol patients (P < .05). There was no significant difference between the recovery times of the two groups.

Desflurane was more cost-effective than propofol. Although desflurane patients experienced more nausea, this did not affect their discharge time.

Key words: Desflurane, cost, propofol, outpatient surgery.

**Introduction**

Increased popularity of outpatient surgery, improved anesthetic techniques, and consumer demands have prompted anesthesia providers to choose anesthetics that optimize the patient’s recovery. Propofol and desflurane, two anesthetic agents commonly used in outpatient surgery, have satisfied patient demands for a rapid, clear-headed awakening. However, the need to control medical costs has forced providers to challenge the therapeutic benefits against the higher cost of these anesthetic agents. Previous studies have compared the cost of isoflurane with that of desflurane and of thiopental/isoﬂurane with the cost of propofol; however, research reports comparing the cost of agents with similar recovery profiles, as seen with desflurane and propofol, were not found.

Our study compared the cost of maintenance anesthesia sustained with a desflurane inhalation with the cost of a propofol infusion. Related expenses, such as ancillary drugs and recovery costs, were included in comparing the cost-effectiveness of these agents.

**Materials and methods**

The study was approved by the institutional review board. All subjects gave written informed consent to participate in the study.

Patients enrolled in the study were 18 years and older, ASA physical status I to II, had a body mass index of 28 kg/m² or less, and were scheduled for elective surgery in the outpatient surgery area. Patients were excluded if they were pregnant; had a family or personal history of malignant hyper-
thermia; had an allergy to desflurane, propofol, or their components; or had undergone general anesthesia within the previous 7 days. Patients were randomly assigned to one of two groups: Group 1 received a propofol infusion with 50% nitrous oxide, and group 2 received desflurane with 50% nitrous oxide. Once included in the study, the patient's age, ASA status, gender, body mass index (BMI), type of procedure, and maintenance anesthetic were recorded.

All patients were preoxygenated and received a preinduction dose of fentanyl (1-2 μg/kg). Midazolam (1-2 mg) and/or 1% lidocaine (20-30 mg) were administered by choice of the anesthesia provider. An induction dose of propofol (2-2.5 mg/kg) was administered over 30-60 seconds. After loss of consciousness, atracurium 0.5 mg/kg, vecuronium 0.1 mg/kg, mivacurium 0.25 mg/kg, or succinylcholine 1 mg/kg was used to facilitate intubation. If mask ventilation was used, atracurium 10-20 mg was administered at the discretion of the anesthesia provider.

The desflurane inhalation or propofol infusion was initiated after the induction with propofol and verification of airway patency. Desflurane was delivered by an electrically heated, temperature controlled vaporizer (Ohmeda Tec 6™, Ohmeda, Madison, Wisconsin) at vaporizer settings of 3-8%. The propofol maintenance was administered using a syringe-type infusion pump (Ohmeda 9000™, Steeton, West Yorkshire, England) at 6-12 mg/kg per hour. After intubation and for the duration of the procedure, 50% nitrous oxide was administered along with the maintenance anesthetic agent. The inspired concentration or the infusion rate of the maintenance anesthetic was adjusted according to the patient's clinical signs and hemodynamic responses to surgical stimulation. To exhibit the most realistic clinical situation, the anesthesia provider was allowed to administer a 2, 3, or 4 L/min total carrier gas flow rate. These flow rates were documented and maintained throughout the procedure. Patients received vasopressors, muscle relaxants, and additional narcotic agents as needed.

At the end of the procedure, the propofol infusion or desflurane inhalation was discontinued; the patient then received 100% oxygen. Muscle relaxants were reversed, if necessary, using neostigmine 0.035-0.07 mg/kg and glycopyrrolate 7 μg/kg. Extubation was performed when adequate spontaneous ventilation and airway reflexes returned. Oxygen, by mask, was removed when the patient followed verbal commands and maintained an oxygen saturation over 95%.

After the patients were transferred to the outpatient recovery area, postanesthesia care unit (PACU) nurses, blinded to the study treatment, assessed and documented the patients' experiences of nausea or vomiting. A strip of paper was placed over the maintenance anesthetic section of the anesthesia record; however, the remainder of the record was accessible to the nurses. The PACU nurses asked the patients how they felt and if they were comfortable. The patients were not specifically asked about nausea unless this symptom was spontaneously volunteered. Patients were also observed for retching and vomiting. The nurses reported if the patient required an antiemetic and/or narcotic, and if so the dose and time these medications were administered.

Finally, the nurses documented the length of stay in recovery by reporting the time of discharge from phases I and II. Phase I recovery was considered the PACU where patients receive care immediately after receiving a general anesthetic. Patients were discharged from phase I to phase II when they were hemodynamically stable, alert, and oriented. In the phase II area, patients were allowed to eat, drink, and ambulate. Patients were required to demonstrate ability to sit, stand, tolerate fluids, and void before they could be discharged home. Discharge delays, such as unavailability of phase I transport staff or a late arrival of the patient's transportation to home, were also recorded and corrected for in the analysis of the results.

Duration of anesthesia was defined as the period between the time of induction and the time the anesthetic agents were turned off. All medications administered during the anesthetic period were documented. The cost to the hospital for the maintenance anesthetic was calculated using these formulas:

\[
\text{Desflurane cost} = \frac{\text{inspired concentration} \times \text{flow} \times \text{molecular weight} \times \text{time}}{\text{price/mL} \times \text{density}}
\]

24.12 \times \text{density}

Definitions are as follows:

- **Inspired concentration**—percentage of desflurane on vaporizer dial
- **Flow**—total carrier gas flow rate (N₂O and O₂)
- **Molecular weight**—168 g/mol or daltons (SI units)
- **Time**—minutes
- **Price/mL**—$0.29/mL
- **24.12**—molar volume of desflurane at 21°C
- **Density**—1.47 g/mL

(Personal communication, A. Byer, product manager, Ohmeda)
Propofol cost = \( \text{price/mL} \pm (\text{mL of drug used} + \text{mL of drug waste}) \)

Definitions are as follows:

- \( Price/mL = $0.49/mL \)
- \( mL \text{ of drug used} \) — amount of propofol administered during the case
- \( mL \text{ of drug waste} \) — amount of propofol remaining in syringe/open vial

(Personal communication, R. Reed, manufacturing representative, Stuart Pharmaceutical)

The costs of medications administered during the intraoperative and postoperative periods were calculated using a list of drug prices obtained from the hospital pharmacy. Hospital costs were calculated.

A Chi-square test analyzed statistical differences in type of procedure, gender, ASA physical status, incidence of nausea, incidence of vomiting, and narcotic and antiemetic administration between the two groups. Duration of anesthesia, cost of intraoperative and postoperative medications (other than maintenance anesthetic), total cost of all medications, length of stay in recovery areas (phase I and phase II), age, and BMI were analyzed using the \( t \)-test for two independent groups. Finally, a one-way analysis of variance was used to analyze differences in the cost between desflurane and propofol and the cost of desflurane at 2, 3, and 4 L/min flow rates.

**Results**

There were no significant differences between the groups regarding age, gender, ASA status, BMI, duration of anesthesia, and frequency of intubation (Table I). No significant difference was detected in the type of procedure between the two groups (Table II).

The price of desflurane versus propofol as a maintenance anesthetic was found to be significantly different. The average cost of a maintenance infusion of propofol was $31.77 ± 14.44, whereas, the average cost of a maintenance anesthetic with desflurane was $12.99 ± 7.61 (\( P < .05 \)). The average cost of all medications (e.g., anesthetics and ancillary agents) administered in the propofol group was $57.97 ± 20.22 versus $34.86 ± 14.13 for the desflurane group (\( P < .05 \)). The above costs for the propofol group reflect the price of propofol waste, which averaged $3.31. The cost of desflurane at a 2 L/min versus 3 L/min flow rate and 2 L/min versus 4 L/min flow rate was found to be significantly different (Table III). No significant difference was found between the 3 L/min and the 4 L/min flow rates.

The difference in recovery times in phase I and phase II was not statistically significant (Figure 1). Phase II recovery time was not analyzed for two patients in the desflurane group. These two

<table>
<thead>
<tr>
<th>Table I</th>
<th>Demographic data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Propofol group</td>
</tr>
<tr>
<td></td>
<td>(n = 26)</td>
</tr>
<tr>
<td></td>
<td>Desflurane group</td>
</tr>
<tr>
<td></td>
<td>(n = 27)</td>
</tr>
<tr>
<td>Gender</td>
<td>8/18</td>
</tr>
<tr>
<td>Age (years)</td>
<td>40.15 ± 13.18</td>
</tr>
<tr>
<td>Body mass index (kg/cm²)</td>
<td>24.08 ± 2.86</td>
</tr>
<tr>
<td>Anesthesia time (minutes)</td>
<td>68.65 ± 35.86</td>
</tr>
<tr>
<td>ASA physical status (I/II)</td>
<td>16/10</td>
</tr>
<tr>
<td>Mask/intubation</td>
<td>4/22</td>
</tr>
</tbody>
</table>

Chi square = no significance difference

<table>
<thead>
<tr>
<th>Table II</th>
<th>Types of procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Propofol group (n = 26)</td>
</tr>
<tr>
<td></td>
<td>Desflurane group (n = 27)</td>
</tr>
<tr>
<td>Gynecology</td>
<td>13</td>
</tr>
<tr>
<td>Genitourinary</td>
<td>5</td>
</tr>
<tr>
<td>Orthopedic</td>
<td>1</td>
</tr>
<tr>
<td>Ear, nose, and throat</td>
<td>2</td>
</tr>
<tr>
<td>General</td>
<td>5</td>
</tr>
</tbody>
</table>

Chi square = no significance difference

<table>
<thead>
<tr>
<th>Table III</th>
<th>Cost of desflurane at 2, 3, and 4 L/min flow rates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 L/min (n = 8)</td>
</tr>
<tr>
<td>Cost per minute ($)</td>
<td>0.16 ± .02*</td>
</tr>
<tr>
<td>Cost per patient ($)</td>
<td>9.99</td>
</tr>
</tbody>
</table>

Values are mean ± SD. *Significantly different from 3 and 4 L/min group; \( P < .05 \).
patients were transferred to extended stay beds until they could be discharged later in the evening. Inability to void and closure of the phase II recovery area were cited as reasons for the first patient's transfer to an extended stay bed. The second patient was transferred after approximately 4 hours in phase II. This patient was unable to void or ambulate and complained of pain, nausea, and dizziness.

Complaints of nausea were found to be significantly different between the two groups: 41% for the desflurane group and 12% for the propofol group ($P < .05$) (Figure 2). Differences in the incidence of vomiting and antiemetic administration were not statistically significant.

There were no significant differences in opioid analgesia, muscle relaxant, or reversal agent administration between the two groups during the intraoperative period. However, patients given propofol did receive significantly more midazolam than patients who received desflurane (Figure 3). The frequency of postoperative narcotic administration was comparable between the two groups (Figure 4).

**Discussion**

In our study, the cost of propofol as a maintenance anesthetic was significantly higher than that of desflurane as a maintenance anesthetic. As a matter of fact, we found that propofol was 2.4 times more expensive than desflurane. Aitken and Farling compared the cost of total intravenous anesthesia using propofol and inhalation anesthesia using isoflurane. They found that propofol was 1.5 to 2 times more expensive than isoflurane. No studies were found comparing the costs of desflurane and propofol.

In a cost comparison of inhaled anesthetics, Weiskopf and Eger concluded that the carrier gas flow rate was a primary determinant of inhalation anesthetic cost. In our study, a comparable number of patients received carrier gas flow rates of 2, 3, and 4 L/min as selected by the anesthesia provider. We analyzed the cost of desflurane at these different flow rates. The cost of desflurane was higher at the 3 and 4 L/min flow rates than at the 2 L/min flow rate. Higher inspired concentrations of the inhaled anesthetic at the 3 L/min flow rate may have offset a cost difference between the 3 and 4 L/min flow rates. Although we did not analyze the cost of the carrier gases themselves, lower flow rates could reduce the cost of carrier gases in both the propofol and desflurane groups.

Wetchler recommended that drug waste should be included in the total cost of administered anesthetics. The seal maintained between the desflurane bottle and vaporizer during filling helped avoid waste. On the other hand, propofol may cost more, in part, because it is packaged as a preservative-free, single-patient-use agent. Therefore, any opened propofol remaining after case completion was wasted. During discussion with and observation of anesthesia providers, it was noted that practitioners filled syringes with propofol from a 20 mL ampule or 50 mL vial at the start of the case. Practitioners who needed additional agent, would draw up propofol from a 20 mL ampule. Therefore, waste was calculated as the difference between the amount drawn up and the amount actually given.

Since there was no difference in recovery time between the two groups, recovery costs (e.g., nursing hours) were not calculated and were assumed to be equal. The recovery times for patients in our
study were consistent with previous studies that also examined differences in recovery times between patients who received propofol and desflurane as maintenance anesthetics. The two patients whose phase II recovery times were not calculated were both in the desflurane group. Although they were discharged later the same day, the criteria for discharge from the extended stay unit were different. Their recovery times would have skewed the phase II recovery times for desflurane. Therefore, we felt it appropriate to remove them from phase II recovery analysis. Second, the reason for transfer may have been related to surgical rather than anesthetic complications.

Wrigley et al compared induction, maintenance, and recovery characteristics of patients given desflurane or propofol as the maintenance anesthetic. They found that the propofol group received more muscle relaxant than the desflurane group. Since volatile agents potentiate muscle relaxation, desflurane patients would be expected to require less muscle relaxant than the propofol patients. Although the cost of muscle relaxants was higher in our propofol group, this was not significantly higher. Anesthesia provider's choice in administering muscle relaxants may have influenced this lack of significance. Frequently, patients were not redosed after the intubating dose of muscle relaxant. Furthermore, patients in both groups who were not intubated often received 5-10 mg of atracurium to facilitate mask ventilation.

Finally, there was very little variation in the muscle relaxant used. Most of our patients received atracurium as a muscle relaxant. Of the two patients who did not receive atracurium, one received an intubating dose of mivacurium, with no further...
muscle relaxants administered. The second patient received succinylcholine for a rapid sequence induction, followed by a maintenance dose of atracurium. Both patients were in the propofol group.

In our study, anesthesia providers were not blinded to the type of anesthetic the patients received and were not restricted in choosing the ancillary agents to be administered. We found that the cost of midazolam in the propofol group was higher than the cost of midazolam in the desflurane group. This significant difference implies that more propofol patients received midazolam than desflurane patients. Veselis et al demonstrated that recall can occur when propofol, administered at dosages greater than or equal to 75 μg/kg per minute, was used as the sole anesthetic. Although our propofol group received dosages greater than 75 μg/kg per minute, concern with recall may have prompted anesthesia providers to administer more midazolam when patients were given propofol as the maintenance anesthetic.

Of the patients in our study receiving desflurane, 41% experienced postoperative nausea, compared to 12% who experienced postoperative nausea receiving propofol. The results were significant and consistent with previous studies, which compared recovery characteristics of propofol and desflurane. These studies found that incidence of nausea ranged from 0% to 13% for patients in the propofol groups and 25% to 50% for patients in the desflurane groups.

We did not find a difference in the incidence of vomiting between the two groups. Our results were consistent with Lebenbom-Mansour et al and Rapp et al whose methods were similar to ours. A significant increase in the incidence of vomiting may have been prevented by responsive postanesthesia care unit nurses who administered an antiemetic early after the complaint of nausea. In fact, the use of antiemetics in the desflurane group was greater, but not significant (P = .06), when compared to the propofol group. None of the previous studies analyzed differences in antiemetic administration between desflurane and propofol groups.

Since the incidence of nausea was increased, more emetic prophylaxis may be required when using desflurane. The hospital acquisition cost of agents commonly used for emetic prophylaxis are as follows: droperidol 1.25 mg, $0.15; metoclopramide 10 mg, $0.30; scopolamine hydrobromide transdermal patch, $3.00; and ondansetron 4 mg, $17.04. Even if the most expensive antiemetic was used with a desflurane inhalation, the cost would still be less than using a propofol infusion without an antiemetic.

Wetchler recommended that indirect costs, such as equipment charges, patient satisfaction, and anesthetic-related hospitalization, influence the patient's total hospital cost. The cost of capital equipment was not calculated since the infusion pumps and vaporizers were supplied by the pharmaceutical companies at no additional charge to the provider. We did not assess patient satisfaction or postdischarge problems related to anesthesia (e.g., readmission due to nausea and vomiting). Since decreased patient satisfaction may affect repeat hospital business and anesthesia-related hospitalization may directly increase hospital costs, further study is needed to assess these indirect expenses.

In conclusion, a maintenance anesthetic using desflurane was more cost-effective than a maintenance anesthetic using propofol. Although desflurane patients experienced more nausea, this did not affect discharge time. However, in terms of patient satisfaction, more effective emetic prophylaxis may be necessary when using desflurane as the maintenance anesthetic. The price of administering an antiemetic would be offset by the savings from using desflurane.

REFERENCES

3. Smiley RM, Ornstein E, Matteo RS, Pantuck EJ, Pantuck CB.


(10) Weiskopf RB, Eger EI. Comparing the costs of inhaled anesthetics. Anesthesiology. 1993;79:1413-1418.


AUTHORS

Eileen M.C. Kurpiers, CRNA, MS, received her MS in Nurse Anesthesia in August 1994 from Abbott Northwestern Hospital School of Anesthesia, Minneapolis, Minnesota. She is presently working as a staff nurse anesthetist at St. Luke's Hospital, Duluth, Minnesota.

John Scharine, CRNA, MS, received his MS in Nurse Anesthesia in August 1994 from Abbott Northwestern Hospital School of Anesthesia, Minneapolis, Minnesota. He is presently working as a staff nurse anesthetist at Sinai-Samaritan Hospital, Milwaukee, Wisconsin.

Sandra L. Lovell, CRNA, MA, MS, is a didactic instructor in three nurse anesthesia programs and an adjunct faculty member at St. Mary's College of Minnesota and at the University of St. Thomas. She is also a staff nurse anesthetist at Hennepin County Medical Center, Minneapolis, Minnesota.

ACKNOWLEDGMENT

We would like to thank the Abbott Northwestern Hospital Day Surgery nurse anesthetists, anesthesiologists, and the preoperative and PACU nurses who assisted in the data collection process. Special thanks to Dr. Richard Engwall for his involvement in the success of our project.