ORIGINAL ARTICLE

Anesthetic maintenance with propofol infusion is less expensive per minute of surgery than sevoflurane or desflurane

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ABSTRACT

Objective: Cost comparison between three common anesthetic agents.

Design: Retrospective analysis. Patients had been randomized to anesthetic maintenance with either desflurane, sevoflurane, or propofol.

Setting: Operating room in an academic medical center

Patients: 103 patients undergoing general endotracheal anesthesia. Patients were ASA class I-III and between 18 and 75 years old. Cardiac, Neurologic, and regional cases were excluded.

Outcome Measures: Volatile anesthetic cost was determined using the following formula: Cost = [(concentration)(FGF)(duration)(MW)(cost/ml)]/[2412)(D)]. To determine propofol cost, average infusion rate (mcg/kg/min.), patient weight, and duration were measured. Cost for each agent was then divided by surgical time to compare the results on a cost/min. basis.

Results: Per minute of surgery, propofol was the least expensive agent for anesthetic maintenance at $0.12/min. Sevoflurane cost $0.18/min and desflurane cost $0.48/min. The differences between all three agents were statistically significant ($p < 0.05$). Propofol maintenance was associated with a higher intra-operative fentanyl dose. The average fentanyl dose in the propofol group was 468 mcg, sevoflurane was 321 mcg, and desflurane was 284 mcg. There was no association between intra-operative fentanyl dose and anesthetic maintenance cost per minute of surgery. Surgical time did not significantly differ between the three groups and averaged over three hours.

Conclusion: Anesthetic maintenance with propofol may help peri-operative physicians deliver care in the most cost effective manner possible.

Key words: Propofol; Sevoflurane; Desflurane; Cost; Anesthetic maintenance

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INTRODUCTION

The surgical environment has transformed from primarily inpatient to primarily outpatient. To maximize return on capital investment, ambulatory surgery as a percent of total surgery has increased from 15% in 1980 to 75% in 2003.[1] While the cost of anesthetic maintenance for an individual case may be low, in aggregate anesthetic agents account for a substantial portion of the overall pharmacy budget: 5-13% with institutional costs increasing along with surgical volume.[2] In the United States, the recent passage of the Affordable Care Act will increase cost containment efforts throughout the entire healthcare system.[3] Increased financial pressures should incentivize hospitals, pharmacies, and physicians to cooperate with the aim of improving quality and slowing spending growth.[4]

Medication acquisition cost varies between institutions. Price is determined by a negotiated contract between hospitals and pharmaceutical companies with discounts offered for bulk purchases.[5] While governmental policy dictates price to a certain extent, in the United States, medicare is prohibited from directly negotiating prices with the pharmaceutical industry.[6]

Propofol is a generic medication and the price has decreased substantially over time. Consequently, older cost analyses have[7,8]found volatile anesthetics to be less expensive than propofol and newer studies have found the reverse to be true.[9] Although generic, propofol is still technically difficult to manufacture, prone to contamination, and therefore subject to critical shortages.[10] As medication prices change in response to market forces and government intervention, anesthetic cost must be continually reassessed.

Important goals for peri-operative physicians are to reduce cost and enhance OR efficiency. Therefore, this subset analysis of a prospective, randomized study proposes to determine the cost of anesthetic maintenance with desflurane, sevoflurane, and propofol per minute of surgical time in adult patients undergoing general endotracheal anesthesia for non-cardiac and non-intracranial surgeries. Additionally, as medication costs vary across institutions and time, this study utilizes easily-reproducible metrics that can faciliatate continual medication cost appraisal.

METHODOLOGY

Following institutional IRB approval, a subset analysis of the multi-center Postoperative Delirium and Post Anesthesia Cognitive Recovery Study (trial.gov number: NCT00507195) was performed. This retrospective analysis included 103 patients undergoing general endotracheal anesthesia for non-cardiac and non-intracranial surgical procedures at Keck Medical Center of USC. Patients were between 18 and 75 years old, ASA class I-III, and had no neurological deficits. Patients were excluded for the following reasons: drug abuse history, cognitive impairment, psychiatric disorders, pregnancy, breast-feeding, or side effect to a study medication. Additionally, patients undergoing neuraxial or regional anesthesia were excluded. Following informed consent, patients were randomly assigned in consecutive order in allocation blocks with a size of 7 and a ratio of 2:2:3.

Patients were pre-medicated with either fentanyl (<1 μg/kg) IV or propofol (<0.5 mg/kg) IV. Lidocaine (1 mg/kg) IV, propofol (2-3 mg/kg) IV, fentanyl (2-4 μg/kg) IV, and a non-depolarizing neuromuscular blocking drug was used for induction. Following tracheal intubation, anesthesia was maintained according to pre-operative randomization assignments: desflurane and fentanyl, sevoflurane and fentanyl, or propofol and fentanyl. Propofol was infused at 10 mg/kg/hr for the first 10 minutes, 8 mg/kg/hr for the next 10 minutes, and 6 mg/kg/hr for the remainder of the case. Fentanyl was administered in 0.7 μg/kg boluses as necessary. The assigned anesthetic agent was stopped at skin dressing and neuromuscular blockade was reversed.

Patients were mechanically ventilated with a 1:1 mixture of air and oxygen. Ventilation was adjusted to achieve an end-tidal carbon dioxide of 30-35 mmHg. For postoperative analgesia, 1 g IV acetaminophen was started at skin closure and continued postoperatively (1 g TDS).

Medication prices were obtained from the hospital pharmacy. Other fixed costs such as anesthesia machines, monitoring equipment, infusion pumps or hospital overhead were not included in the cost analysis. Disposables such as infusion lines and endotracheal tubes were not considered. Finally, indirect and intangible costs of the anesthetic technique were not considered.

Volatile anesthetic cost was determined from the concentration of gas delivered based on vaporizer setting (%), fresh gas flow (L/min.), duration of volatile anesthetic administration, molecular weight (g), cost per ml, a factor to account for the molar volume of the gas at 21 C (2412), and density (g/ml).[11]

Cost ($) = [(concentration)(FGF)(duration)(MW)(cost/ml)]/[2412)(D)]

In the calculation, the average concentration (%) for the case was determined from the vaporizer setting recorded in the anesthetic record per 5-minute interval. Desflurane cost was based on a MW of 168 g, cost of $0.96/ml, and density of 1.45 g/ml. Sevoflurane cost was based on a MW of 201 g, cost of $0.90/ml, and density of 1.51 g/ml.

Propofol cost was determined using the average infusion rate per 5-minute interval (mcg/kg/min.), patient weight, duration of administration, and propofol concentration. The cost was then determined using a price of $8 per 100 ml bottle. To account for waste, the total volume of propofol administered was rounded up to the nearest 100 ml.

Vaporizer setting and average propofol infusion rate were obtained via manual abstraction from the paper record. The total cost for each anesthetic agent was divided by surgical time (incision to wound closure) to facilitate equivalent comparison.

All patients were induced with propofol. The induction dose was not factored into the anesthetic maintenance cost for either the propofol infusion or the volatile anesthetics since the price of 20 ml and 100 ml propofol bottles differ and since the induction method was standardized. Fentanyl cost was $0.278 per 100 μg vial.

Data were analyzed using Student's t-test to compare means and Pearson's correlation coefficient to assess linear relationships between variables. Continuous variables are presented as mean ± standard deviation. Statistical analysis was performed on BMDP statistical software, version 8.1 (Statistical Solutions, Los Angeles, CA). A value of $p < 0.05$ was considered statistically significant.

RESULTS

The average patient age in the study was 52 years old with the desflurane group being slightly younger (Table 1). The majority of patients were female (66%). Although the differences were not statistically significant, the sevoflurane group had the shortest average surgical time (197 min.) compared with either the propofol (229 min.) or desflurane groups (220 min.). The propofol group required a statistically significant higher fentanyl dose (462 μg) compared with either volatile anesthetic group (sevoflurane = 321 mcg, desflurane = 284 μg).

The average propofol maintenance infusion rate was 150 ± 30 μg/kg/min. The average administered sevoflurane concentration was 1.78 ± 0.24 % at a fresh gas flow rate of 2.04 ± 0.18 L/min. The average administered desflurane concentration was 5.86 ± 0.54 % at a fresh gas flow rate of 1.78 ± 0.35 L/min. Propofol was the least expensive per minute of surgical time at 0.12 ± 0.031 $/min. Sevoflurane cost 0.18 ± 0.027 $/min. Desflurane was the most expensive at 0.48 ± 0.11 $/min. Table II illustrates that the difference in cost/min. of surgical time between all three groups was statistically significant. The average fentanyl cost for anesthetic maintenance with propofol was 0.0056 ± 0.0022 $/min, sevoflurane was 0.0045 ± 0.0019 $/min, and desflurane was 0.0036 ± 0.0016 $/min.

Table 1: Comparison between groups

Parameter	Propofol	Sevoflurane	Desflurane
Number of Patients	34	34	35
Male	11	12	12
Age	53.6 ± 13.2	52.3 ± 10.5	49.7 ± 13.4
Surgery Time (min.)	229 ± 99	197 ± 130	220 ± 56
Fentanyl Dose (mcg)	462 ± 182	321 ± 137	284 ± 127
Cost ($/min.)	0.12 ± 0.03	0.18 ± 0.03	0.48 ± 0.11

Table 2: Statistical analysis (p-value)

Comparison groups	Age	Fentanyl (μg)	Surgical Time	$/min.
Propofol vs. Sevofluane	0.64	<0.001	0.26	<0.001
Propofol vs. Desfluane	<0.001	<0.001	0.65	<0.001
Sevoflurane vs. Desflurane	0.38	0.25	0.34	<0.001

Using Pearson's correlation coefficient, linear relationships between cost/min. and age, cost/min. and surgical time, and cost/min. and fentanyl dose for the three different anesthetic agents were assessed. There were no significant relationships found with $R<|0.3|$.

DISCUSSION

The lack of immediate pharmacy oversight and increased emphasis on efficiency and cost containment in the modern surgical environment mandates that anesthesiologists continually evaluate their technique with regards to cost. In a conventional setting, a physician prescribes a medication, a pharmacist reviews and verifies the order, and a nurse administers the medication. In the OR, an anesthesiologist assumes all three roles.

Quantifying the amount of volatile anesthetic administered is not intuitive. A primary challenge is that while volatile anesthetics are commercially available as liquids, they are administered as gases. Throughout the case, vaporizer settings change frequently as the anesthetic depth is titrated in accordance with the ongoing surgical stimulus. Anesthetic gas consumption depends on fresh gas flow rate and the addition of other gases.[12] While rebreathing in a circle breathing circuit decreases waste,[13] it obscures volatile anesthetic consumption quantification and is not commonly used in clinical practice.

A primary limitation to this retrospective analysis was that volatile anesthetic use was determined using manual extraction from the chart instead of weighing the vaporizers. Variations in negotiated price between different hospitals also can limit reproducibility of this study. Finally, fentanyl was administered as needed during the case and not per standardized protocol. As fentanyl has a known MAC sparing effect,[14] larger intraoperative fentanyl doses could decrease the propofol maintenance infusion rate required, lower cost, and create confounding. However, cost/min. and fentanyl dose was not significanly correlated for the three agents. Additionally, the direct fentanyl medication cost was negligible averaging less than one half cent per minute in each group.

In this study, the average desflurane flow rate was 1.78 L/min and the average sevoflurane flow rate was 2.04 L/min. While the manufacturer recommends administering sevoflurane using fresh gas flow rates > 2 L/min to avoid Compound A induced nephrotoxicity,[15] there are no such restrictions with desflurane. However, even if desflurane had been administered at half the flow rate, the cost would still have been greater than either propofol or sevoflurane.

Desflurane should produce the most rapid recovery as it is the volatile agent with the lowest blood and tissue solubility.[16] However, in a recent literature review, while early recovery (eye opening and obeying commands) was marginally quicker (< 5 min.) with desflurane and sevoflurane compared with propofol, there was no difference in home readiness. Additionally, propofol decreased post-operative nausea and vomiting.[17] If improved early recovery increased the number of cases performed daily, this advantage could only be exploited in operating rooms with short cases and high turnover. In this study, the average case duration was longer than three hours in each anesthetic maintenance group. Furthermore, decreasing PONV incidence with propofol could create additional savings and improve patient satisfaction. A potential concern when exclusively using propofol is the lack of real-time feedback guaranteeing medication delivery as there is no "end-tidal" propofol measurement.

While increased collaboration between pharmacists and anesthesiologists may help reduce waste, improve efficiency, and contain cost, improving scheduling and efficiency in the operating room has a greater potential to reduce operating room costs.[18] Indeed, it has been shown that staff costs are the greatest expense of any anesthetic administered.[19]

CONCLUSION

In conclusion, propofol was the least expensive anesthetic maintenance agent: propofol cost 0.12 $/min. at 150 μg/kg/min., sevoflurane 0.18 $/min. at 1.78% and 2.04 L/min., and desflurane 0.48 $/min. at 5.86% and 1.78 L/min. Although propofol maintenance was associated with a larger intra-operative fentanyl dose, cost/min. did not correlate with fentanyl dose. While appropriate resource utilization is an important goal, cost minimization is only one factor. The overarching goals of enhancing patient safety, satisfaction, and surgical outcome temper all others.

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