A Cost Analysis of the Laryngeal Mask Airway for Elective Surgery in Adult Outpatients

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Background: Since the introduction of the laryngeal mask airway (LMA) into the United States in 1991, the device has become widely used in anesthesia practice. The purpose of this economic analysis was to use existing data to evaluate the costs of the LMA relative to three other common airway management techniques and to identify the variables that had the greatest effect on cost efficiency.

Conclusions: We evaluated four airway management techniques for healthy adults receiving an isoflurane–nitrous oxide–oxygen anesthetic for elective outpatient surgery: (1) LMA with spontaneous ventilation; (2) face mask with spontaneous ventilation; (3) tracheal intubation after succinylcholine with subsequent spontaneous ventilation; and (4) tracheal intubation after nondepolarizing neuromuscular blockade and controlled ventilation. We analyzed published clinical studies of the LMA and obtained cost data from Stanford University Medical Center. The best available estimates of the independent variables were incorporated into a baseline case. For each airway technique we derived cost equations that excluded costs common to all four techniques.

Results: Relative to airway management with an LMA, calculated values for the baseline analysis included additional isoflurane costs for use of a face mask ($0.12/min) and for tracheal intubation with ($0.043/min) and without neuromuscular blockade ($0.06/min). With a neuromuscular blocking drug cost of $0.21/min and an LMA cost per use of $20, the face mask with spontaneous ventilation was the cost-efficient airway choice for anesthetics lasting as long as 100 min. Increasing the LMA reuse rate from 10 to 25 made the LMA the least costly airway technique for cases lasting more than 70 min.

Conclusions: If the LMA is reused 40 times, the LMA is the cost-efficient airway choice for outpatients receiving an

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Isoflurane–nitrous oxide–oxygen anesthetic lasting longer than 40 min. This finding does not change if the cost of neuromuscular blockade or the incidence of airway-related complications is varied over a clinically relevant range. (Key words: Economics; cost analysis; Equipment: laryngeal mask airway.)

SINCE the introduction of the non-disposable laryngeal mask airway (LMA) (Intavent International SA, Henley-on-Thames, England) into the United States in 1991, the LMA has become widely used in anesthesia practice. There is a paucity of published economic analyses of devices used in anesthesia. The main advantages of the LMA are its ease of use, the low incidence of postoperative sore throat, elimination of the need for neuromuscular blockade as part of the anesthetic, decreased anesthetic requirements relative to those of the endotracheal tube (ETT) and facilitation of a reliable airway, which frees the anesthesiologist to attend to other tasks.

It is not known if the LMA’s reuse rate affects the device’s cost efficiency relative to airway management by the ETT or by anesthesia face mask. The LMA is reusable but is not guaranteed by the manufacturer for more than 10 autoclave cycles. If the device passes a rigorous pre-use examination, the reuse rate can reach 200–250.

Because adverse outcomes resulting from differences in airway management techniques are rare, we examined clinical data from multiple published studies. By excluding costs common to the alternatives being evaluated and by quantifying the additional costs unique to each alternative, decisions regarding resource allocation can be made more efficiently.

Data used in quantitative economic evaluations include uncertainties and potential biases. By varying independent cost variables, the influence of uncertainties or changes in practice can be determined. The purpose of this economic analysis was to evaluate the costs of the LMA relative to three other common airway management techniques and to identify the variables that had the greatest effect.

materials and Methods
We compared the costs of four techniques for adults. Anesthesiologists (ASA) physical status I, unconscious patient with isoflurane–nitrous oxide–oxygen anesthesia: (1) spontaneous ventilation, (2) spontaneous ventilation with oral Guedel airway; (3) spontaneous ventilation with tracheal intubation after nondepolarizing muscle paralysis (ETT); and (4) spontaneous ventilation with tracheal intubation after depolarizing muscle paralysis (ETT).

To structure this cost analysis, we assumed that each airway technique was the best available monetary estimate. The cost variables obtained from multiple sources were used. From the baseline case, we varied the cost of each variable to assess their importance on the overall cost.

Assumptions
We made the following assumptions.
1. We did not factor in fixed costs (e.g., personnel and equipment) that do not change with volume of cases. The number of general anesthesia cases each center handled was estimated by the center. We did not include the fixed costs in our analysis. We assumed that the centers that were free of these concerns handled more than 400 cases in the previous year.
2. Although we included all costs possible, we included only those related to the airway technique or the device being compared. We did not include anesthesia-related factors such as blood loss.
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4. Although we included all costs possible, we included only those related to the airway technique or the device being compared. We did not include anesthesia-related factors such as bleeding.
5. Although we included all costs possible, we included only those related to the airway technique or the device being compared. We did not include anesthesia-related factors such as bleeding.
COST ANALYSIS OF THE LARYNGEAL MASK AIRWAY

variables that had the greatest effect on cost efficiency.

Materials and Methods

We compared the costs of four airway management techniques for adults, American Society of Anesthesiologists (ASA) physical status 1, undergoing elective outpatient surgery with isoflurane–nitrous oxide–oxygen anesthesia: (1) spontaneous ventilation with an LMA; (2) spontaneous ventilation with a face mask and an oral Guedel airway; (3) spontaneous ventilation with tracheal intubation after suxamethonium and pre-treatment with a nondepolarizing drug; and (4) controlled ventilation with tracheal intubation with nondepolarizing neuromuscular blockade.

To structure this cost analysis, we modeled a baseline case for each airway technique that incorporated the best available monetary estimates of relevant, independent cost variables obtained from the literature and, if not available in published studies, from our institution. From the baseline case, we varied the estimated probability of a complication or a supply's estimated cost to assess their importance on the overall cost equation.

Assumptions

We made the following assumptions.

1. We did not factor in fixed costs (e.g., labor, facility, and equipment) that do not change with airway technique or volume of cases. We considered only variable costs (e.g., oral airway) that change with the number of general anesthetics. For each airway technique, we derived cost equations that included only costs of variables that differed depending on the choice of airway technique. For example, although more face masks are needed if more anesthetics are delivered, the face mask cost was not included in this analysis because face masks are used in all four techniques.

2. Although there are infinite combinations of anesthetic regimens, we selected a standard anesthetic for the four airway techniques, consisting of isoflurane mixed in nitrous oxide and oxygen. By controlling for the costs of the anesthetic itself, we focused on and elucidated the costs associated with a particular airway technique.

3. The LMA undergoes a rigorous preuse examination before placement in a patient. For this reason we did not add extra costs due to LMA failure resulting from previous uses of the device.

4. Health outcomes, risks, and costs of the surgery itself are independent of airway management choice and were excluded from the analysis.

5. Regional anesthesia techniques were not considered.

6. Costs may be seen differently from the points of view of the patient, provider, or society as a whole. The cost to society is the total cost of all different components of society, including the patient's lost productivity. This analysis was performed from the perspective of a capitated managed care environment, in which financial resources for health care are allocated for a specified period of time and in which expenditures during this interval must be contained within the limits of available funds. In this setting, practice strategies that minimize the cost of resources to produce a given outcome are especially important.

Literature Search

We identified all English-language articles on LMAs (key words: equipment, laryngeal mask airway, anesthesia; outpatient; complications: intraoperative, postoperative) by a computerized literature search (MEDLINE) for 1985–1994. We supplemented the search with a review of references from retrieved articles. We estimated the incidence of complications and anesthesia labor costs from published studies in peer-reviewed literature. Estimates of unit costs for each type of airway complication were based on the average cost of a complication multiplied by its incidence. Only complications that had an incidence of greater than 1 in 500,000 were incorporated into the analysis.

Costs of Supplies and Drugs

We used Stanford University Medical Center (SUMC) acquisition costs for supply and drug costs. Data for variable costs other than those for supplies and drugs (e.g., chest radiograph) were obtained from SUMC's cost-accounting system (Clinical Cost Manager, Transition Systems, Boston, MA), which combines clinical and financial cost data to calculate actual variable product costs. For the baseline analysis, an LMA cost per use of $20 was used on the basis of the recommended minimum reuse rate described in the literature of 10 and the device acquisition cost of $200.12 We also incorporated the LMA reuse rate at SUMC. The total number of LMAs (size 3 or 4) purchased and
discarded at SUMC in a 12-month period was 48. The number of anesthetics using LMAs during that period equaled 1,450. We estimated an LMA to be reused an average of 30 (1,450/48) times, which yielded a cost of $6.67 per LMA per case.

Costs Associated with Postoperative Complications

The average cost of postoperative complications was derived from published data and information from the SUMC's Office of the General Counsel (see Results).

Decision Model

By combining costs that do and do not change with the duration of the case, we computed cost functions over the duration of the anesthetic in minutes for each of the four airway techniques. The most cost-efficient airway choice was defined as the technique with the lowest cost for a given case duration.

Results

Main Results

Table 1 lists the costs for the baseline analysis, comparing the LMA with the other airway techniques. The cost efficiency of airway management techniques for healthy outpatients undergoing elective surgery with isoflurane–nitrous oxide–oxygen anesthetics is most explained by the case duration and the number of times the LMA is used before being discarded.

Baseline Case. For the baseline analysis, an LMA reuse rate of 10 with a neuromuscular blockade cost of $0.21/min suggests that the face mask is the cost-efficient airway technique for isoflurane–nitrous oxide–oxygen anesthetics lasting as long as 100 min (fig. 1). For cases longer than 100 min, the ETT with spontaneous ventilation is the least costly choice. Decreased fresh gas flow, 3 l·min⁻¹ for the LMA versus 6 l·min⁻¹ for the face mask, results in decreased volatile agent costs and in the LMA being the preferred cost strategy in cases exceeding 205 min. Furthermore, the ETT with neuromuscular blocking is a greater cost than the ETT with spontaneous ventilation mostly because of the additional cost of the blocking drug (fig. 1). The ETT ventilation has a greater cost than the ETT with spontaneous ventilation because the increased volatile cost with the ETT technique: Substitution of a non–neuromuscular blockade cost ($0.05 to LMA becomes less costly than the ETT ventilation because of the duration of the anesthetic.

Effect of the Laryngeal Mask

To estimate that if the number of times from 10 to 25, the LMA ventilation becomes the cost-efficient choice for isoflurane–nitrous oxide–oxygen anesthetics, the technique with the lowest cost to the patient is the LMA ventilation (fig. 1). The LMA ventilation is a more cost-effective choice when compared to the ETT ventilation for patients requiring anesthetic times exceeding 205 min. Furthermore, the ETT with neuromuscular blocking is a greater cost than the ETT with spontaneous ventilation mostly because of the additional cost of the blocking drug (fig. 1). The ETT ventilation has a greater cost than the ETT with spontaneous ventilation because of the increased volatile cost with the ETT technique: Substitution of a non–neuromuscular blockade cost ($0.05 to LMA becomes less costly than the ETT ventilation because of the duration of the anesthetic.

Table 1. Costs ($) Associated with Each Airway Management Technique

<table>
<thead>
<tr>
<th>Airway Device</th>
<th>ETT (Controlled Ventilation)</th>
<th>ETT (Spontaneous Ventilation)</th>
<th>LMA</th>
<th>Mask</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nondepolarizing drugs</td>
<td>(+)</td>
<td>(+ pretreatment)</td>
<td>(-)</td>
<td>(-)</td>
</tr>
<tr>
<td>Succinylcholine</td>
<td>(-)</td>
<td>(+)</td>
<td>(-)</td>
<td>(-)</td>
</tr>
<tr>
<td>Spontaneous ventilation</td>
<td>(-)</td>
<td>(+)</td>
<td>(-)</td>
<td>(+)</td>
</tr>
<tr>
<td>Costs ($)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oral airway</td>
<td>0.49</td>
<td>0.49</td>
<td>0</td>
<td>0.49</td>
</tr>
<tr>
<td>Airway device</td>
<td>1.73</td>
<td>1.73</td>
<td>20.00</td>
<td>0</td>
</tr>
<tr>
<td>Labor</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0</td>
</tr>
<tr>
<td>Clean blade/LMA</td>
<td>0</td>
<td>0</td>
<td>0.75</td>
<td>0</td>
</tr>
<tr>
<td>Autoclave</td>
<td>0</td>
<td>0</td>
<td>0.75</td>
<td>0</td>
</tr>
<tr>
<td>Drugs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volatile anesthetic ($/min)</td>
<td>0.043</td>
<td>0.06</td>
<td>0</td>
<td>0.12</td>
</tr>
<tr>
<td>Range (0.01–0.10)</td>
<td>0.06</td>
<td>(0.01–0.10)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Muscle relaxant</td>
<td>0.21 ($/m)</td>
<td>2.20</td>
<td>2.20</td>
<td>0</td>
</tr>
<tr>
<td>Range (0.01–0.40)</td>
<td>(0.01–0.40)</td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>NMB reversal</td>
<td>0.60</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PACU morphine</td>
<td>1.50</td>
<td>1.50</td>
<td>0.70</td>
<td>0.70</td>
</tr>
<tr>
<td>Supplies</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suction</td>
<td>2.19</td>
<td>2.19</td>
<td>2.19</td>
<td>2.19</td>
</tr>
<tr>
<td>Yankauer</td>
<td>0.42</td>
<td>0.42</td>
<td>0.42</td>
<td>0.42</td>
</tr>
<tr>
<td>Probability of use (suction and yankauer)</td>
<td>1</td>
<td>1</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>Total</td>
<td>2.61</td>
<td>2.61</td>
<td>0.26</td>
<td>0.26</td>
</tr>
<tr>
<td>Lubricant</td>
<td>0</td>
<td>0</td>
<td>0.02</td>
<td>0</td>
</tr>
</tbody>
</table>

ETT = endotracheal tube; LMA = laryngeal mask airway.

* The dollar cost of the volatile anesthetic drug is not presented in absolute terms. The value reflects the additional isoflurane requirements for each technique.
COST ANALYSIS OF THE LARYNGEAL MASK AIRWAY

Fig. 1. Costs for four airway management techniques in the baseline case (laryngeal mask airway [LMA] reuse rate of 10, neuromuscular blocking [NMB] drug cost $0.21/min). The y intercept of the linear cost functions for each airway technique is derived by summing costs unique to each airway technique that are independent of case duration (e.g., airway device). The slopes of the lines reflect the additional costs unique to a particular airway technique that increase with the length of the case (e.g., NMB drug). Although anesthesia drug costs increase for all airway techniques as the duration of the anesthetic increases, the LMA cost line does not increase over time because the cost equations exclude costs common among the four techniques. For a given case duration (x min), the cost savings between any two techniques equals the difference between the two respective y (dollar) values. Under our baseline assumptions, the cost savings for a 90-min case with use of a face mask compared with an LMA with spontaneous ventilation is $7.84. Management with a face mask is the least costly technique for cases lasting as long as 100 min. For cases lasting more than 3 h, the endotracheal tube (ETT) with NMB is more costly than the ETT with spontaneous ventilation, mainly because of the additional cost of the NMB drug, and the ETT with spontaneous ventilation costs less mainly because of the high cost of the LMA at a reuse rate of 10.

Fig. 2. The cost of neuromuscular blockade (NMB) does not affect the cost efficiency of the laryngeal mask airway (LMA) at reuse rates greater than 25. The horizontal axis represents the number of times an LMA is reused before being discarded. The vertical axis represents the case duration (minutes) at which the LMA is the least costly airway management choice. The curved lines represent the case duration at which the LMA becomes the cost-efficient choice at two NMB drug costs. The analysis predicts that because the cost implications of an LMA reuse rate greater than 25 are large, the cost of NMB does not affect the case duration at which the LMA becomes the most cost-efficient strategy among the four alternatives. However, if the LMA reuse rate is less than 10, then NMB costs affect the case duration at which the LMA is most cost efficient.

for cases exceeding 205 min. For a case lasting 120 min, the ETT with neuromuscular blockade has a greater cost than the ETT with spontaneous ventilation, mainly because of the additional cost of neuromuscular blocking drug (fig. 1). The ETT with spontaneous ventilation has a greater cost than the LMA at 120 min because of the increased volatile agent requirement with the ETT technique. Substituting a decreased neuromuscular blockade cost ($0.02/min) suggests that the LMA becomes less costly than the ETT or face mask if the duration of the anesthetic exceeds 185 min.

Effect of the Laryngeal Mask Airway Reuse Rate. We estimate that if the number of uses per LMA increases from 10 to 25, the LMA with spontaneous ventilation becomes the cost-efficient airway management choice for isoflurane-nitrous oxide-oxygen anesthetic lasting longer than 70 min (fig. 2). If the LMA is reused more than 25 times, neither the cost of neuromuscular blocking drugs nor the incidence of airway-related complications affects the overall cost efficiency of the LMA in ASA physical status 1 adults undergoing elective outpatient surgery.

Increasing the LMA reuse rate from 25 to 40 increased the cost savings of the LMA over the ETT and spontaneous ventilation for a 90-min case to $7.62. If the LMA reuse rate of 30 at our institution is increased to 40, the case duration at which the LMA is the cost-efficient airway choice for adult outpatient anesthetics decreases from 55 to 40 min. At an LMA reuse rate of 40, the cost advantage of the LMA over the ETT with

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controlled ventilation and neuromuscular blockade for a 90-min case was $23.52.

**Data from Published Studies**

**Costs of Volatile Anesthetic Drugs.** Patients breathing spontaneously through an ETT require 0.20–0.53% greater end-tidal isoflurane concentration for postincision maintenance of general anesthesia than patients in whom an LMA and spontaneous ventilation are used.15,16 There is no difference in anesthetic requirement for outpatients breathing spontaneously through an LMA or a face mask.11 Patients in whom controlled ventilation with an ETT and neuromuscular blockade, obtained by titrating vecuronium, were used required 0.37% more postincision end-tidal isoflurane than patients receiving an LMA and ventilating spontaneously.9

In calculating volatile agent cost, we assumed an average fresh gas flow through a semiclosed absorption system of 3 L·min⁻¹ for the LMA and tracheal intubation techniques and 6 L·min⁻¹ for the face mask (assume greater flows because of air leaks). At a cost of $0.71/ml isoflurane, 0.37% and 0.53% additional isoflurane concentrations translated into $0.043 and $0.06 more per minute of isoflurane (see appendix for calculation of the cost per minute of 1% isoflurane with a fresh gas flow of 1 L·min⁻¹).15,20

**Costs of Neuromuscular Blocking Drugs.** The cost of neuromuscular blocking drugs can range from $0.015/min (pancuronium, case duration of 5 h, no “wasted” drug) to $0.40/min (mivacurium, 60-min case, “wasted” drug [any drug drawn up for patient and not used is discarded]) (table 2). For the baseline analysis we used a neuromuscular blocking drug cost of $0.21/min. In this study, neuromuscular blocking drugs were associated with ETT use or as pretreatment (defasciculating) dose, which we assumed to be one-tenth the intubating dose of a nondepolarizing drug.

**Costs of Converting Airway Management Techniques.** The LMA is replaced by the ETT in 0.38% of patients.21 We incorporated this LMA-to-ETT conversion incidence into the LMA costs. In calculating face mask costs, we assumed a 2% incidence of conversion to the ETT (e.g., unanticipated need for neuromuscular blockade) and a 9% incidence of conversion of the LMA (e.g., unanticipated difficulty with face mask ventilation in a patient with a beard).

**Postanesthesia Care Unit Costs.** In a prospective randomized study of ambulatory patients given an LMA versus an ETT, patients with an LMA required significantly less morphine in the postanesthesia care unit than did patients with an ETT (8 vs. 15 mg).22 We were unable to find any data to support differences in postoperative wake-up time, discharge times, and vomiting among patients with ETT or LMA.17,18

### Table 2. Estimated Costs per Anesthetic of Complications Vary by Airway Choice

<table>
<thead>
<tr>
<th>Airway Option</th>
<th>Incidence (%)</th>
<th>Estimated Cost ($)</th>
<th>$ Cost/Aesthetic</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspiration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ETT</td>
<td>0.005 (0.001-0.05)</td>
<td>1330</td>
<td>0.067</td>
<td>29, 30</td>
</tr>
<tr>
<td>LMA</td>
<td>0.025 (0.001-0.1)</td>
<td>1330</td>
<td>0.33</td>
<td>31, 32</td>
</tr>
<tr>
<td>Mask</td>
<td>0.025 (0.001-0.1)</td>
<td>1330</td>
<td>0.33</td>
<td>33</td>
</tr>
<tr>
<td>Dental injury</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ETT</td>
<td>0.01 (0.1-0.007)</td>
<td>580</td>
<td>0.58</td>
<td>22, 34, 35</td>
</tr>
<tr>
<td>LMA</td>
<td>0.0001 (0.0-0.01)</td>
<td>580</td>
<td>0.01</td>
<td>33</td>
</tr>
<tr>
<td>Mask</td>
<td>0 (0-0.001)</td>
<td>580</td>
<td>0</td>
<td>33</td>
</tr>
</tbody>
</table>

ETT = endotracheal tube; LMA = laryngeal mask airway.
COST ANALYSIS OF THE LARYNGEAL MASK AIRWAY

Table 4. Costs Excluded from the Analysis

<table>
<thead>
<tr>
<th>Costs Excluded</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extra few minutes to insert ETT/LMA than mask^11</td>
<td>unlikely to delay start of surgery</td>
</tr>
<tr>
<td>ETT associated with greater hemodynamic changes than mask or LMA^10</td>
<td>in healthy outpatients unlikely to be clinically significant</td>
</tr>
<tr>
<td>Differences in ventilatory patterns^8</td>
<td></td>
</tr>
<tr>
<td>Decreased coughing with LMA^7 at end of case</td>
<td>in healthy outpatients unlikely to be clinically significant</td>
</tr>
<tr>
<td>Neuromuscular reversal drug or opioid side effects</td>
<td>difficult to separate from other drug side effects</td>
</tr>
<tr>
<td>Environmental waste costs increased with face mask^26</td>
<td>monetary cost low and difficult to measure</td>
</tr>
<tr>
<td>Higher incidence of oxygen desaturation with mask^11</td>
<td>no evidence to indicate this change patient outcome</td>
</tr>
<tr>
<td>Regurgitation while using LMA^27</td>
<td>conflicting data with unclear clinical significance</td>
</tr>
<tr>
<td>Negative pressure pulmonary edema^28</td>
<td>differences in incidence among face mask, LMA, and ETT are unknown and probably small</td>
</tr>
<tr>
<td>Cranial nerve injury^39</td>
<td>ETT are unknown and probably small</td>
</tr>
<tr>
<td>Education of the practitioner on LMA use</td>
<td>negligible after initial learning period</td>
</tr>
</tbody>
</table>

ETT = endotracheal tube; LMA = laryngeal mask airway.

In a prospective cost study, we evaluated face mask costs, neuromuscular conversion to the endotracheal tube, and the costs of complications in patients who underwent face mask ventilation.

**Institutional Cost Study**

Costs of Complications. Incidence and estimated costs of complications are listed by complication in table 3. Table 4 lists costs not included in our analysis. The estimated average cost of pulmonary aspiration of gastric contents (clinically significant pneumonia requiring treatment) in a patient who has not eaten for 8 h was calculated to be $1,330: two chest radiographs ($110), physician labor ($300), prolonged stay in the postanesthesia care unit ($280), and 12 h of supplemental oxygen during an extra day of regular inpatient care ($640).

The average payment by SUMC’s Office of the General Counsel for 11 claims for dental injury caused by laryngoscope in 1992–1993 was $580. This finding agreed with that of Warner et al. The estimated cost per anesthetic for prolonged apnea from homozygous cholinesterase deficiency was $0.19 (incidence 0.03125%); estimated cost of diagnosis and treatment ($600). Other succinylcholine-related risks such as arrhythmia, hyperkalemia, and increases in intragastric, intraocular, and intracranial pressure were not included, because the magnitude of their importance is very small. An additional malignant hyperthermia (MH) cost after succinylcholine was not included as patients in this analysis were also exposed to a volatile anesthetic known to trigger the onset of MH.

**Labor Costs.** The labor cost of cleaning laryngoscopes and autoclaving the LMAs was $0.75 for each task (SUMC technician’s hourly wage and benefits ($15/h) multiplied by the 3 min required for each task).

**Discussion**

The goals of this economic analysis were to elucidate and compare the costs of the LMA in spontaneous ventilating patients with three other common airway management strategies for adult outpatients undergoing isoflurane–nitrous oxide–oxygen anesthesia for elective surgery. Our results suggest that the face mask is a cost-efficient choice for cases less than 40 min. If the LMA reuse rate approaches 40, airway management with the LMA becomes the least costly technique for cases longer than 40 min. At an LMA reuse rate greater than 25, neuromuscular blocking drug costs are not important in determining the overall cost efficiency of the LMA.

**Laryngeal Mask Airway versus Endotracheal Tube**

Although ETT placement does afford added protection against pulmonary aspiration of gastric contents, the ETT has traditionally been placed in elective outpatient surgery mainly for ease of maintaining the airway. Most of the cost savings afforded by the LMA with spontaneous ventilation come from eliminating neuromuscular blocking drugs and decreased volatile anesthetic concentration. The increased postincision anesthetic
requirements in patients with an ETT may be attributable to the increased intraoperative stimulus from the ETT and from central sensitization to subsequent stimuli induced by laryngoscopy and tracheal intubation.9

Our analysis was from the perspective of a managed care environment. We did not include indirect costs to the patient such as succinylcholine myalgia, which occurs in 5–83% of patients.24 In addition, we did not factor in that using an LMA instead of an ETT reduces the risk of sore throat from 15–49% to 2–15%,5–8,11,24,25 If the analysis were done from the point of view of society, economic losses related to such complications would need to be included and could be measured by willingness to pay or human capital approaches.15,26 The overall effect of airway complications in this setting is likely to be small.

Laryngeal Mask Airway versus Face Mask

Face mask airway management may require frequent readjustments to maintain the airway, in which case a harness or strap may be helpful. In cases where the airway requires frequent readjustment of the face mask, there may be an associated “inconvenience cost” to the practitioner. Because the LMA does not require ongoing manual support after proper placement to maintain a patent airway, airway deterioration caused by fatigue is reduced.11 Tasks such as preparing and giving medications, positioning the patient, and record keeping, which occupy 23% of postintubation task completion time, may need to be performed with the second hand or not at all should two hands be required. The value of having hands free is underscored by studies that show that the mean task density for experienced anesthesiologists is 5.7 tasks/min with occasional needs for task densities exceeding 15 per minute.27 Accounting for an “inconvenience” cost may partly explain the emerging clinical trend at our institution to use the LMA for cases less than 40 min.

We considered LMAs in a specific surgical population where the LMA was not contraindicated. Analysis of the LMA for other clinical scenarios, such as in patients with difficult airways or with alternative anesthetic regimens (e.g., total intravenous anesthesia) may yield different results. Clearly, any patient specific requests need to be integrated by clinicians in airway management decisions.

Significant monetary savings may be associated with using the LMA. For example, for an ambulatory surgical center performing 4,000 cases (each case lasting 90 min), the potential cost reduction of using LMAs at a reuse rate of 40 instead of the ETT and spontaneous ventilation may approach $55,000 (4,000 cases × $7.62/case). The LMA may prove to be especially cost attractive for ambulatory procedures that do not require the use of muscle relaxants.2

For any given operating room suite, the cost efficiency of the LMA will depend on the local reuse rate. With the reuse rate of 50 at our institution, our economic analysis suggests that placing an LMA for an isoflurane nitrous oxide-oxygen anesthetic that lasts more than 55 min will result in cost savings. The cost profile of the LMA improves by increasing the reuse rate. Provided the device is sterilized in the appropriate manner, the upper limit for autoclavings of an intact LMA can approach 200–250.13,14 The clinically reliable LMA reuse rate has not been studied. One institution with extensive clinical experience with the LMA discards LMAs after 40 uses to eliminate possible defective devices.28 At this use rate the LMA is the least costly airway choice for cases lasting more than 40 min. For more cost-efficient airway management during outpatient anesthesia, the costs associated with increased education and the provision of incentives to keep the LMA use rate greater than 25 need to be evaluated against the benefits of greater reuse rates.

Our results provoke questions about new technologies that may introduce costs that cannot be passed onto the patient or other payers. Airway management with an LMA frees the provider’s hands, but this advantage does not result in identifiable dollars saved or identifiable dollars lost. We need to clarify how the ergonomics of LMA use can translate into improved patient care within a managed care organization. For each patient, anesthesiologists need to formulate a suitable balance between cost containment issues and patient well-being.

Appendix: Calculation of Isoflurane Cost

Isoflurane (1%) cost/min with fresh gas flow of 11·min⁻¹

= (vapor concentration (%) × (FGF (1·min⁻¹)) × (molecular weight (g)) × (cost ($·ml⁻¹))/2.412) × (density (g·ml⁻¹))/(%I × (11·min⁻¹)) × (197.4 g/(0.71 ($·ml⁻¹))/2.412) × (1.50 (g·ml⁻¹)) = $0.059/min

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References

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