Evidence-Based Medicine in Otolaryngology
Part 10: Cost-Effectiveness Analyses in Otolaryngology

Lisa Caulley, MD, MPH1,2, Danielle Rodin, MD, MPH3,4, Shaun Kilty, MD2,5, Gregory Randolph, MD6, Myriam G. Hunink, MD, PhD7,8, and Jennifer J. Shin, MD, SM6*

Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

Abstract
Clinicians seek to pursue the most clinically effective treatment strategies, but costs have also become a key determinant in contemporary health care. Economic analyses have thus emerged as a valuable resource to both quantify and qualify the value of existing and emerging interventions and programs. Cost-effectiveness analyses estimate the benefits gained per monetary unit, providing insights to guide resource allocation. Herein, we delineate the related concepts and considerations to facilitate understanding and appraisal of these analyses, so as to better inform the stakeholders in our otolaryngology community.

Keywords
cost-effectiveness, decision sciences, economic evaluations, cost-utility

Received February 4, 2019; accepted May 1, 2019.

As new and costly health care technologies continue to rapidly emerge, financial constraints necessitate a judicious approach to decision making and resource allocation. Stakeholders must determine what interventions have good “value for money,” and cost-effectiveness analyses (CEAs) provide a quantitative approach to integrate data that reflect both clinical impact and cost.1-9 These assessments have been employed as an economic directive of resource allocation10-24 and may have an expanding role in health care models as they move from volume- to value-based frameworks.25 Thus, our objective is to provide otolaryngologists with a clear understanding of the concepts, theories, and considerations that form the foundation for CEAs. We present key steps in understanding and appraising CEAs and provide a summary of economic analyses of otolaryngology–head and neck surgery (OTO-HNS) interventions and programs.

Perspective
Central to an economic analysis is a fundamental question: how can we maximize benefits in the setting of limited resources? The answer varies depending on which stakeholder is answering the question. Thus, whether a health care program is deemed cost-effective depends on the perspective of the study. For example, a societal perspective takes into account all costs and effects associated with a resource or program, irrespective of who incurred the cost or effect.2,26,27 This perspective also accounts for the alternative use of resources outside of the health care sector, which may benefit society in nonmedical ways.28 A CEA performed from a societal perspective thus includes both formal and informal health care sector costs, as well as non–health care sector costs, such as lost productivity due to illness and social services–related costs.

In contrast, a health care sector perspective provides a narrower viewpoint, including only formal health care costs reimbursed by third-party payers or out-of-pocket payments from patients. This perspective reflects the considerations of a decision maker within the health care system itself. While some may argue that a publicly funded health care system

1Department of Epidemiology, Erasmus MC, Rotterdam, the Netherlands
2The Ottawa Hospital Research Institute, Ottawa, Ontario, Canada
3Department of Radiation Oncology, University of Toronto, Toronto, Ontario, Canada
4Radiation Medicine Program, Princess Margaret Cancer Centre, Toronto, Ontario, Canada
5Department of Otolaryngology–Head and Neck Surgery, University of Ottawa, Ottawa, Ontario, Canada
6Department of Otolaryngology, Harvard Medical School, Boston, Massachusetts, USA
7Department of Epidemiology and Department of Radiology, Erasmus MC, Rotterdam, the Netherlands
8Center for Health Decision Sciences, Harvard T. H. Chan School of Public Health, Boston, Massachusetts, USA

*These authors contributed equally to this manuscript.

Corresponding Author:
Jennifer J. Shin, MD, SM, Department of Otolaryngology, Harvard Medical School, 45 Francis Street, Boston, MA 02115, USA.
Email: jennifer_shin@meei.harvard.edu
should always consider the perspective of those individuals in society who pay into it, for-profit or private organizations may argue that a societal perspective is unnecessary and rely solely on a financial directive to maximize their budget.29

For instance, a CEA that is performed from a health care sector administrative perspective may conclude that operating room closures would be economical within the health care budget. However, reducing access to surgery may not be cost-effective from the societal perspective, since patients may be unable to maintain employment and productivity while awaiting surgery. A societal perspective would account for cost shifting between health care and societal sectors when determining cost-effectiveness. To this end, the choice of payer perspective will have important implications for the scope of costs, benefits, and analyses considered in a CEA and must be carefully considered in the initial stages of designing a CEA.3,28

The US Public Health Service panel recommended that all CEA studies conduct 2 analyses—one from the health care sector perspective and one from the societal perspective—to promote comparability and emphasize the value and consequences of decision making from different viewpoints.29 The research question and intended audience should guide the decision to emphasize one perspective over the other.30 In contrast, the National Institute for Health and Care Excellence, an agency that provides guidance to improve health and social care in the United Kingdom, recommends the adopted perspective reflects costs to the National Health Services and personal and social services, as well as outcomes of all direct health effects.31 Similarly, the Canadian Agency for Drugs and Technologies in Health recommends CEAs adopt the publicly funded health care payer perspective. For this health care system, analysts are advised to consider the costs incurred by the Canadian public payer and all meaningful health effects for patients and their informal caregivers.32

**Types of Economic Analyses**

To determine the cost-effectiveness of a health care strategy, the costs and health effects of alternative interventions are compared to establish the trade-off between additional resources and clinical benefits.33 Here, we will consider the 2 main approaches: (1) CEAs, which include cost-utility analysis (CUA), and (2) cost-benefit analysis (CBA). These economic methodologies vary based on how the clinical effectiveness or outcomes are valued.

CEAs compare costs relative to health effects, which reflect changes in states of health and well-being at various points over an individual’s lifetime.2 In basic CEAs, assessments of health effects often focus on the quantity of life, including life years (LYs) gained, lives saved, and events prevented; they may also focus on health outcomes, such as voice or hearing improvement.33-35 A focus on quality of life (ie, LYs) is simple but fails to incorporate the quality of any life that is gained. For instance, consider a new chemotherapeutic agent that averts the risk of death from nasopharyngeal carcinoma in a patient who is 50 years of age, so that the patient survives until age 55; this agent is said to save 5 LYs.33 If this chemotherapy causes severely debilitating side effects, however, the loss of function is not incorporated into the analysis.

When both quality and quantity of life are relevant,33,36 a CUA is the appropriate approach.33,37 A CUA is a type of CEA that measures the benefits of interventions as gains in health.36 In this approach, health outcomes are adjusted for quality of life using validated instruments to determine an individual’s willingness to live in a particular state of health that has been affected by disease, treatment, or toxicity. More desirable health states receive a greater value, or weight and are thus favored in the analysis. For instance, in a study of frontal sinusotomy for chronic rhinosinusitis, absence of major intraoperative complications received a greater weight.24,38 As further detailed in the preceding installment of this series,39 utilities are preference weights that describe the value of a given health state measured on a scale from 0 (death) to 1 (optimal health). These weights are then used to generate quality-adjusted life years (QALYs).36,37,40 QALYs represent the summary measure of a health intervention in terms of time spent in a series of these quality-weighted health states.38,39,41 Given the multidimensional health outcomes evaluated in surgical interventions, QALYs are commonly used to integrate measures of survival and quality of life.1,35,40 In the previous example, a patient who takes the chemotherapeutic agent for nasopharyngeal carcinoma may have chronic renal failure as a complication of therapy, which reduces his or her quality of life from 1 to 0.6. Taking into account the quality of prolonged survival, the treatment would provide the patient with an additional 3 QALYs (ie, 0.6 × 5 LYs).

Quantification of utilities and ultimately QALYs can be a complex process, and we have discussed these concepts in the preceding installment of this series.39 In brief, health state valuation estimates can be derived from direct measurements via preference-based methods. One such method is the standard gamble, in which respondents are asked to value health states according to how much they would risk death to transcend a given health state. A second approach is the time trade-off technique; here, respondents quantify how time in a diseased state compares to time in an optimal

---

**Box 1. Relevant Terminology for Cost-Effectiveness Analysis Discussed in This Article.**

<table>
<thead>
<tr>
<th><strong>Acronym</strong></th>
<th><strong>Definition</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>CEA</td>
<td>cost-effectiveness analysis</td>
</tr>
<tr>
<td>CUA</td>
<td>cost-utility analysis</td>
</tr>
<tr>
<td>ICER</td>
<td>incremental cost-effectiveness ratio</td>
</tr>
<tr>
<td>LY</td>
<td>Life year</td>
</tr>
<tr>
<td>NHB</td>
<td>net health benefit</td>
</tr>
<tr>
<td>NMB</td>
<td>net monetary benefit</td>
</tr>
<tr>
<td>QALY</td>
<td>quality-adjusted life year</td>
</tr>
<tr>
<td>WTP</td>
<td>willingness to pay</td>
</tr>
</tbody>
</table>
health state.\textsuperscript{2,39,41-45} These decisional utility assessments have clear benefits, but critics of preference-based approaches note the potential for error when respondents attempt to forecast the value of a hypothetical, future health state.\textsuperscript{46} These potential errors may be magnified in states that are sensitive to temporal preferences.\textsuperscript{47} For instance, the clinical scenario of an immediate, disfiguring postsurgical state may be valued differently if presented to a young, healthy individual compared to a clinical scenario of the same postsurgical state in 40 years.

An alternative to this decisional approach is an experience-based approach in which utilities are measured based on personal experience, \textit{during} the active experience.\textsuperscript{48-50} This firsthand experience may be assessed through means such as a visual analog scale or a general health instrument.\textsuperscript{46} Proponents of an experience-based approach posit that patients who have experienced a condition firsthand should have more valid valuations than those who have only envisioned a different health state. This approach, however, may lead to near-normal valuations for conditions where patients can adapt or change their internal standards.\textsuperscript{38,42,51} This experience-based approach has also been criticized for not defining a comparable sacrifice or opportunity cost to directly quantify a specific utility value.\textsuperscript{46} The indirect approach to utility measurement assesses a range of attributes through a validated general health questionnaire. The EuroQol 5 Dimensions (EQ-5D), Six-Dimensional Health State Short Form (SF-6D), and the Health Utilities Index (HUI) 3 are examples of instruments that can provide indirect measures of health utility.\textsuperscript{36,38,52,53} Analysts select an appropriate measurement tool for the query of interest, since utility values may vary depending on the instrument selected to elicit them.\textsuperscript{54-57}

In contrast to CEAs that measure costs and health effects in different units, CBAs summarize both individual costs and utilities in monetary values, and the results estimate the net monetary benefit (NMB) of an intervention.\textsuperscript{1,29,30,37,58,59} An intervention is favored if the monetary value of all benefits exceeds the cost of the investment.\textsuperscript{1,36,58} For instance, a new chemotherapeutic agent for nasopharyngeal carcinoma could be projected to provide $10,000 per year of life saved, or a benefit of $50,000 over 5 years. The justification for CBAs comes from the fact that they account for a range of benefits, including nonhealth benefits.\textsuperscript{36,58} Although CBAs are widely used in the economic realm, CBAs are less commonly applied in the health care setting due to the ethical concerns of assigning a monetary value for health effects (eg, dollars for human lives). As such, the primary focus of this article will be on CEAs in health care resource valuation and their ability to quantify total cost relative to health effects.\textsuperscript{1,59,60}

**Cost Estimates and Related Terms**

Costs of care have traditionally been broadly categorized as “direct” or “indirect.” Direct costs refer to formal health care goods and services consumed by individuals, while indirect costs refer to the inferred value of an individual’s time or productivity.\textsuperscript{2,29,61-64} This categorization was updated in 2016 by the US Public Health Service panel of experts, who suggested that costs should be reclassified as those incurred within the health care sector and those incurred outside of the health care sector.\textsuperscript{2,29,62} Formal health care costs reflect costs directly associated with the use of an intervention and the consequences of that use.

When evaluating the formal costs of an intervention, the costs of events occurring with the intervention are compared to the costs of events occurring without the intervention. Costs accrued from implementation of an intervention are categorized as initial costs, induced costs, and averted costs. For instance, in implementing a screening program for hearing loss, the initial costs would stem from physician visits, audiology equipment, and related personnel. Induced costs would arise from follow-up of patients with abnormal screening results and treatment of confirmed hearing loss. The costs saved from events avoided by implementing the hearing loss screening program are summarized as averted costs, such as early detection of adult sensorineural hearing loss before it has a detrimental effect on quality of life and productivity (Table 1).\textsuperscript{1,29,62}

Informal health care costs refer to the costs associated with obtaining health care that are not incurred by the health care system (and thus are only included in the analysis from the societal perspective), such as patient time, unpaid caregiver time, and costs for transportation to and from health care facilities. Other non–health care considerations include effects on future productivity and consumption, social services, criminal justice, education, housing, and environment (Table 1 delineates additional details and examples).\textsuperscript{39,62}

Non–health care sector consequences are quantified in terms of resources relevant to the clinical scenario under consideration. For example, a patient who undergoes a mandibulotomy and free fibular flap reconstruction for advanced oral cavity carcinoma may require modifications to his or her home to accommodate limitations in mobility and rehabilitation needs postoperatively, creating additional personal costs.\textsuperscript{65} In addition, the recovery time following surgery may preclude return to work, resulting in lost wages and productivity. These cost consequences to the patient would not be borne by the health care sector but should be included in the total costs of an intervention or strategy in the societal perspective of a CEA.\textsuperscript{66}

**Designing a Cost-Effectiveness Analytic Model**

The early planning stages of the CEA are critical for defining a relevant research question and designing an effective decision analysis model to avoid future analytical pitfalls.\textsuperscript{2} It is important to identify all relevant alternatives for diagnostic tests and treatment interventions of a CEA, particularly through a search of controlled trials, since they can offer high-level evidence of the risks and benefits of
The Cochrane Library can be consulted to obtain systematic reviews of randomized controlled trials (RCTs) and references to RCTs. For topics where clinical trials are lacking or impractical (eg, rare events), observational studies can be rigorously and objectively evaluated for evidence to inform models. Epidemiological studies and patient registries are valuable to model the natural history of diseases over patients’ lifetimes.

A fundamental tool in performing a CEA is a decision-analytic model. A decision model illustrates the sequences of events that can occur following alternative decisions in a logical framework, as well as the probabilities of health states and health outcomes associated with each possible pathway. The decision analysis model for a CEA should simulate outcomes across all possible decisions by illustrating and quantifying the distribution of alternatives in the context of risks, benefits, and costs. This hypothetical model incorporates a cost of $500 per individual screened and assumes that patients with abnormal hearing will subsequently undergo observation with audiometry or hearing amplification, which may provide a greater quality of life for eligible candidates.

### Time Horizon

The time period of analysis for a CEA is referred to as the time horizon. The appropriate time horizon of a study can be difficult to determine and to an extent varies according to the study question. The time horizon should be long enough to capture important intended and unintended downstream consequences of the intervention. A limited time horizon can underestimate the overall benefit of an intervention. For instance, an analysis of the first year may be sufficient to account for initial capital costs and annualized maintenance fees when implementing an adult hearing loss screening program. However, this time frame will inherently bias against downstream effects that take several years to manifest.

### Table 1.

Cost Components Included in the 2 Recommended Reference Case Perspectives as Recommended by Sanders et al and Illustrated through a Cost-Effectiveness Analysis of a Hearing Loss Screening Program.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Cost of Implementation of a Hearing Loss Screening Program</th>
<th>Reference Case Perspective</th>
<th>Health Care Sector</th>
<th>Societal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Formal health sector</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Health</td>
<td>Initial costs paid by third-party payers (physician visits, audiology equipment, audiology personnel)</td>
<td>★</td>
<td>★</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Induced costs paid by third-party payers (follow-up for hearing loss identified on audiology screening, treatment of reversible causes of hearing loss)</td>
<td>★</td>
<td>★</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Averted costs of third-party payer (treatment of hearing loss prior to complications)</td>
<td>★</td>
<td>★</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Costs paid out of pocket by patients (conventional hearing aids, bone-anchored hearing aids, FM system)</td>
<td>★</td>
<td>★</td>
<td></td>
</tr>
<tr>
<td><strong>Informal health sector</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Health</td>
<td>Patient-time costs</td>
<td>—</td>
<td>★</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unpaid caregiver-time costs</td>
<td>—</td>
<td>★</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transportation costs</td>
<td>—</td>
<td>★</td>
<td></td>
</tr>
<tr>
<td><strong>Non–health care sectors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Productivity</td>
<td>Labor market earnings lost</td>
<td>—</td>
<td>★</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cost of unpaid lost productivity due to hearing loss</td>
<td>—</td>
<td>★</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cost of uncompensated household management</td>
<td>—</td>
<td>★</td>
<td></td>
</tr>
<tr>
<td>Consumption</td>
<td>Future consumption unrelated to health</td>
<td>—</td>
<td>★</td>
<td></td>
</tr>
<tr>
<td>Social services</td>
<td>Cost of social services associated with a hearing loss screening program</td>
<td>—</td>
<td>★</td>
<td></td>
</tr>
<tr>
<td>Legal or criminal justice</td>
<td>Number and cost of crimes related to hearing loss screening program</td>
<td>—</td>
<td>★</td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td>Impact of hearing loss screening program on educational achievement of population</td>
<td>—</td>
<td>★</td>
<td></td>
</tr>
<tr>
<td>Housing</td>
<td>Cost of hearing loss screening program on home improvements</td>
<td>—</td>
<td>★</td>
<td></td>
</tr>
<tr>
<td>Environment</td>
<td>Cost considerations from toxic waste pollution by hearing loss screening program</td>
<td>—</td>
<td>★</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>Other impacts (including friction costs)</td>
<td>—</td>
<td>★</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: FM system, wireless assistive hearing devices; —, this variable would not be included in “Health Care Sector” and would only be considered in “Societal Perspective.”
Guidelines for CEAs (2003) recommended a period of evaluation of 10 years at full implementation to account for capital costs and total costs during that period. Therefore, through a CEA, analysts have the additional benefit of using a decision model to extrapolate health effects beyond the shorter duration of a clinical trial. For example, health effects measured in a clinical trial of a new intervention for hearing loss management with a follow-up period of 2 years can be used to inform a decision model. The decision model will integrate the results of the clinical trial over a 20-year time horizon while accounting for conditions of uncertainty to provide decision makers with long-term outcomes for the intervention for hearing. In the absence of clinical trial data, observational data or carefully delineated assumptions, if data are lacking, can also be used in decision models to estimate long-term outcomes and lifetime prognoses.

Discounting

Discounting reflects the cost and potential benefits lost by spending money to receive immediate benefits now rather than in the future, that is, the opportunity cost of spending current money. This concept has important implications for CEAs comparing surgical and medical interventions. Surgical interventions are more likely to incur increased upfront costs, while medical interventions accumulate long-term costs, which can make surgical interventions appear less cost-effective if a discount rate is not performed. As such, discounting allows a fair comparison of interventions and programs where the costs and outcomes accrue at different times. The standard US discount rate for CEAs is 3%, applied to both costs and health effects, but can be further explored in sensitivity analyses that investigate a range of potential discount rates (eg, 0%-5%).

Reporting Results

In presenting and appraising results for CEAs, relevant reporting guidelines should be consulted. For instance, the Consolidated Health Economic Evaluations Reporting Standards statement provides recommendations to ensure study results meet the accepted standards for reporting CEAs, allowing for ease of comparison between study methods and outcomes. Furthermore, country-specific guidelines, including statements from the US Public Health Service panel, the National Institute for Health and Care Excellence, and the Canadian Agency for Drugs and Technologies in Health, provide recommendations for modeling approaches and techniques for conducting CEAs.
Incremental Cost-Effectiveness Ratios

The end product of a CEA is expressed as an incremental cost-effectiveness ratio (ICER; Table 2), which shows the cost for achieving an additional unit of health for one intervention compared to another.2,29 Commonly, 2 or more interventions are compared, and the costs of these interventions are also measured against societal willingness-to-pay (WTP) thresholds. For example, a proposed adult hearing loss screening program would ideally be more effective than not implementing the program and be cost-saving and/or have an ICER below an accepted WTP threshold. Interventions that provide additional benefits at reduced costs are said to dominate their alternatives.

Table 2. Primary Outcomes for Economic Analysis Models.

<table>
<thead>
<tr>
<th>Type of Model</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost-benefit analysis</td>
<td>Net Societal Benefit = Incremental Benefit (in monetary units) - Incremental Costs</td>
</tr>
</tbody>
</table>

Abbreviations: CER, cost-effectiveness ratio; ICER, incremental cost-effectiveness ratio; QALY, quality-adjusted life year.

Willingness to Pay

Once an ICER is determined, the analyst must confirm that the incremental increases in costs and effectiveness are below the threshold that the public, government, or a third-party payer is willing to spend on a new health care strategy (Figure 2).39,78 Historically, a WTP threshold of US$50,000 per QALY was deemed to be an appropriate benchmark for the value of care. However, recent increases in health care spending have called this historical threshold into question and suggested WTP thresholds of 2 to 6 times its value.60,79-82 The ongoing controversy around recommendations for WTP thresholds highlights the importance of considering individual and societal valuations of health in health care decision making.

Net Benefits Framework

The formula to calculate the ICER can be rearranged to establish the net health benefit (NHB) and net monetary benefit (NMB), which are single quantifiable measures of benefit.83 The NHB is calculated as the incremental effectiveness (E) minus the total cost. Total cost is converted into QALY equivalents by dividing incremental cost (C) by the WTP threshold (WTP; Figure 3). The NHB is arguably more easily interpreted than an ICER, where an NHB of greater than 0 refers to a cost-effective strategy and a higher NHB reflects a more cost-effective strategy. In the setting of CBAs, which focus on the monetary value of benefits, the NMB is often calculated as the incremental effectiveness multiplied by the WTP minus the incremental costs, with a similar ease of interpretability of results (Figure 2).78

Uncertainty in Cost-Effectiveness Analyses

After creating a decision model that estimates risks, benefits, and costs associated with a research question, a sensitivity analysis should be performed to explore the effects of uncertainties on the final decision and gain insight into variables driving a decision.1,78 The impact of model parameters can be evaluated through a series of 1-way, 2-way, or multivariable sensitivity analyses where salient parameters are varied across a plausible range above and below the base estimates derived from evidence from the literature.78 To understand the impact of multivariable uncertainty on the cost-effectiveness results, a probabilistic sensitivity analysis should be conducted to estimate the probability that each therapy is cost-effective for a given WTP threshold.1,78
Over multiple iterations, the decision model randomly selects a value of each parameter from its distribution to provide a measure of uncertainty around the outcome estimates and to estimate the likelihood of making the wrong decision.\cite{1,78,84} For example, a decision model that evaluates the cost-effectiveness of radiation therapy as compared to transoral robotic surgery for oropharyngeal cancer would incorporate the range of probabilities for posttreatment disease-free survival, recurrence rates, and toxicity from the available literature to provide a probability of cost-effectiveness for each respective treatment strategy at a selected WTP threshold.

**Limitations and Controversies in Cost-Effectiveness Analyses**

**Distribution of Health Resources**

Despite extensive inputs, decision models can fail to provide information relevant to decision makers. The theoretical foundation of CEAs rests on a utilitarian approach to health care resource distribution, such that the goal focuses on maximization of health benefits to all members of society.\cite{7,85} This approach to medical decision making may fail to consider disadvantaged subgroups and address issues of social justice; there are ethical controversies as the values of health states, cost, and health effects vary by race, culture, and social group.\cite{35} For instance, patients of lower socioeconomic status would derive the greatest benefit from a head and neck cancer screening program as the incidence of head and neck cancer has been found to be higher amongst this patient population.\cite{87-89} However, it is difficult to ensure a weighted distribution of health benefits in a CEA of a head and neck cancer screening program that is intended to serve an entire society. Thus, although decision makers may be interested in the ability to reduce social inequalities in race, sex, or social class through a distributive health effect, these goals may conflict with the standard universal translation of CEA.\cite{90}

Physicians will often seek ethical justifications for prioritizing the health of the sickest and most disadvantaged parties in keeping with the theory of social justice.\cite{91} However, establishing a consensus on which populations qualify as the most disadvantaged or how much weight this hierarchical status should introduce has proven difficult among clinicians, policy makers, and economists.\cite{90,91} How should an adult with severe obstructive sleep apnea be economically prioritized in relation to a child with bilateral, profound sensorineural hearing loss? In the context of standard values of health in CEAs, it can prove difficult to establish prioritization for selected populations.

As utilitarian standards encourage maximizing the aggregate health of the population, a QALY is limited in its ability to distinguish between large gains for a small number of individuals vs small gains for a large number of individuals. Welfare economics refers to optimal resource allocation and its impact on social welfare.\cite{92} It forms the basis of utilitarian public policy in theory but can be difficult to put in to practice. To this end, treatment of widely prevalent diseases that provide small incremental benefit but remain inexpensive to the health care system will be prioritized over costly treatment measures that provide a large health effect to a small group of patients.\cite{35,90,91} It also highlights the ethical dilemma in prioritizing individual health over societal health. What are the societal opportunity costs when an individual patient with advanced laryngeal cancer receives societal resources in the context of minimal additional health effect? There is an obvious lack of consensus on if/when an individual should be denied treatment, even ineffective treatment, if it no longer benefits societal health.\cite{28}

**Age of Beneficiaries**

Implicit in QALYs is the assumption that 1 year of perfect health carries the same weight for every individual.\cite{90} However, this concept of age-independent comparability remains a controversial topic among health economists and health policy makers.\cite{93} Murray and Lopez\cite{94} presented the assumption that gaining years of life in young adulthood was preferred to gaining years of life in childhood or older adulthood, citing both economic and social arguments for introducing age weights. For instance, surgical resection of an oropharyngeal cancer will appear more cost-effective for a younger patient compared to an older patient because more QALYs can be gained in a younger patient.\cite{21} For policy makers, this has ethical and economic implications for prioritization of funding, such that health care funding could then be more likely to target diseases that affect younger people.\cite{95} Age weighting may in fact be redundant given that analyses for younger individuals will inherently emphasize LYs lost that are proportional to their age.\cite{96} As no consensus has been reached regarding the use of age weighting, the WHO recommends analysts consider the appropriateness of age weights according to their study design.\cite{58}

**Generalizability of Results**

The external validity of CEAs may be limited by the study perspective or the setting from which the data are derived (eg, time or location of cost data). Data derived locally, particularly cost, are subject to wide variation and thus limited in generalizability. Furthermore, the results of a CEA may not be generalizable to select patients, as surgical intervention outcomes vary by patient age, severity of disease, and comorbidities.\cite{35} External validity may be improved if an analyst complies with the recommendation of the US Public Health Service panel to present the reference case analysis from the societal and health care sector perspective, and subgroup analyses are carried out for relevant patient groups.\cite{29,35}

Cross-validation of models, whereby models are compared to previously reported models addressing the same research question, can be used to validate study findings. However, the issues of diverging results for different decision models for the same research question is not an infrequent occurrence, as seen in 4 studies that explored the
### Table 3. Cost-Effectiveness Analyses in the Otolaryngology–Head and Neck Surgery Literature Published in 2017 as Identified in PubMed

<table>
<thead>
<tr>
<th>Author</th>
<th>Target Population</th>
<th>Intervention vs Standard of Care</th>
<th>Perspective</th>
<th>Time Horizon</th>
<th>Base Case Incremental Cost-Effectiveness Ratio (2017 USD)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naunheim et al</td>
<td>Bilateral vocal cord paralysis</td>
<td>Endoscopic management</td>
<td>Health care sector</td>
<td>27 years</td>
<td>—</td>
</tr>
<tr>
<td>Rodin et al</td>
<td>Early stage oropharyngeal cancer</td>
<td>Tracheostomy</td>
<td>Societal</td>
<td>Lifetime</td>
<td>Dominated</td>
</tr>
<tr>
<td>Hojjat et al</td>
<td>Asymmetric sensorineural hearing loss</td>
<td>Transoral robotic surgery</td>
<td>Health care sector</td>
<td>Not specified</td>
<td>$86,009/QALY</td>
</tr>
<tr>
<td>T1 gadolinium-weighted MRI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$27,660/tumor diagnosis</td>
</tr>
<tr>
<td>T2-weighted MRI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$15,943/tumor diagnosis</td>
</tr>
<tr>
<td>Al-Qurayshi et al</td>
<td>High-risk thyroid surgery</td>
<td>No intraoperative nerve monitoring</td>
<td>Health care sector</td>
<td>20 years</td>
<td>$49,353/QALY</td>
</tr>
<tr>
<td>Scangas et al</td>
<td>Chronic rhinosinusitis</td>
<td>Medical therapy</td>
<td>Health care sector</td>
<td>36 years</td>
<td>—</td>
</tr>
<tr>
<td>T1 gadolinium-weighted MRI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$5657/QALY</td>
</tr>
<tr>
<td>T2-weighted MRI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$5952/QALY</td>
</tr>
<tr>
<td>Hojjat et al</td>
<td>Idiopathic unilateral vocal cord paralysis</td>
<td>No imaging</td>
<td>Health care sector</td>
<td>Not specified</td>
<td>—</td>
</tr>
<tr>
<td>Kempfle et al</td>
<td>Obstructive sleep apnea</td>
<td>CT</td>
<td>Health care sector</td>
<td>15 years</td>
<td>$3416/diagnosis</td>
</tr>
<tr>
<td>Scangas et al</td>
<td>Chronic rhinosinusitis with nasal polyps with asthma</td>
<td>Medical therapy</td>
<td>Health care sector</td>
<td>35 years</td>
<td>—</td>
</tr>
<tr>
<td>Scangas et al</td>
<td>Chronic rhinosinusitis with nasal polyps without asthma</td>
<td>Medical therapy</td>
<td>Health care sector</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Shapiro et al</td>
<td>Thyroid nodules</td>
<td>Molecular testing</td>
<td>Health care sector</td>
<td>2 years</td>
<td>$28,500 per reduction of 1 patient undergoing surgery</td>
</tr>
<tr>
<td>Crowson et al</td>
<td>Asymmetric hearing loss</td>
<td>Standard-of-care screening MRI</td>
<td>Health care sector</td>
<td>Not specified</td>
<td>—</td>
</tr>
</tbody>
</table>

Abbreviations: CT, computed tomography; MRI, magnetic resonance imaging; QALY, quality-adjusted life year; USD, US dollars.

*Costs are reflected in 2017 USD. If year of cost collection was not specified in the manuscript, the year of submission for publication was assumed to reflect the year of cost collection. All costs were uplifted to 2017 USD using the consumer price index.109
cost-effectiveness of transoral robotic surgery in the management of oropharyngeal cancer. The diverging results in these studies stem from differences in data sources, subpopulations under investigation, and assumptions from each study. Influential factors such as stage, human papillomavirus, nodal status, and extracapsular spread differed among investigations. It is important for decision makers to consider the population and assumptions relevant to their clinical question when critically appraising the literature for decisions about resource allocation. Probabilistic and sensitivity analyses can explore the uncertainty of parameters and identify parameters driving the variability in ICER.

**Cost-Effectiveness Analyses in the OTO-HNS Literature**

Although cost-related publications have been less than in other fields, CEAs in OTO-HNS have increased in quantity and quality. A published review of the Tufts CEA registry from 1976 to 2011 revealed that only 2.0% of the CUAs evaluated otolaryngology interventions. The study demonstrated a higher proportion of published CUAs in otology (31.1%) than in endocrine surgery (19.6%), sleep medicine/surgery (18.0%), head and neck surgery (13.0%), pediatric otolaryngology (8.2%), allergy (6.6%), and rhinology (3.3%). There were no CUAs related to facial plastics uncovered in their search.

In follow-up to this publication, to help illustrate the more recent CUAs performed in OTO-HNS, we also searched the CEAs in the OTO-HNS literature published in 2017. The results were limited to English PubMed publications from January 1, 2017, to December 31, 2017. Text words used included cost-effectiveness analysis, cost-utility analysis, and otolaryngology. This search produced 52 studies, and the abstracts of these studies were screened for inclusion. The ICERs of primary CEA studies were extracted and the key aspects of identified CEAs are presented in Table 3. The studies have typically arisen in areas of clinical controversy. Most studies were presented from the health care sector perspective, with 1 study presenting a societal perspective. The studies identified presented a minimum 15-year time horizon. CEA data were available to inform decisions about a wide range of interventions, including recurrent laryngeal nerve monitoring in thyroidectomy, transoral robotic surgery in oropharyngeal cancer, and timing of tracheostomy following prolonged intubation. There have also been data published in pediatrics, specifically the relative value of universal watchful waiting, universal antibiotics, and no antibiotics in children with acute otitis media.

While the limited external validity of CEAs may reduce their ability to act as a primary tool for health care resource allocation, they may serve as a health care alternative to “consumer reports” for surgeons, whereby treatments found to have low ICERs are deemed “best buys” and high ICERs are “worst buys.” Furthermore, they can evaluate the cost-effectiveness of medical practice guidelines to ensure that recommendations for standardized health practices are implemented in a resource-conscious manner. For instance, Sun et al demonstrated that use of the watchful waiting strategy as recommended by the American Academy of Pediatrics guidelines for acute otitis media management was a dominant strategy compared with standard-of-care practices from a societal perspective, confirming that recommended guidelines resulted in improved health outcomes and cost savings.

**Conclusion**

Financial constraints in the health care realm are becoming increasingly apparent. In this environment, CEAs are designed to help clinicians compare health care interventions to determine cost-effective strategies for health care quality improvement. CEAs evaluate the incremental health gains in the context of costs of different interventions to facilitate comparison. As the issue of value for care progressively moves to the forefront, surgeons may need CEAs to advocate for new technology and frame difficult clinical decisions. Otolaryngologists should appreciate the strengths and limits of CEA projections and interpret results in the context of other desirable societal goals.

**Author Contributions**

Lisa Caulley, contributed to the design of the work, drafted the work, revised it critically for important intellectual content, provided final approval of the version to be published, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved; Danielle Rodin, contributed to the design of the work, acquisition of relevant information for the work, revised it critically for important intellectual content, provided final approval of the version to be published, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved; Shaan Kittly, contributed to the design of the work, acquisition of relevant information for the work, revised it critically for important intellectual content, provided final approval of the version to be published, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved; Myriam G. Hunink, contributed to the design of the work, acquisition of relevant information for the work, revised it critically for important intellectual content, provided final approval of the version to be published, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved; Jennifer J. Shin, conception of the work and substantial contributions to the work, drafting the work and revising it critically for important intellectual content, final approval of the version to be published.
published, agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Disclosures

Competing interests: Lisa Caulley holds a doctoral award (Frederick Banting and Charles Best Canada Graduate Scholarships [CGS–D]) from the Canadian Institutes of Health Research. Shaun Kilty receives research funding from Roche-Genentech, AstraZeneca, Sanofi, GlaxoSmithKline, and Medtronic and a speaker’s bureau from Meda Pharmaceuticals. Gregory Randolph receives textbook royalties from Evidence-Based Otolaryngology. Myriam G. Hunink receives royalties from Cambridge University Press for a textbook on decision making and reimbursement for travel and lodging from the European Society of Radiology and the European Institute for Biomedical Imaging Research. Jennifer J. Shin receives textbook royalties from Elsevier. Lisa Caulley holds a doctoral award, the American Academy of Otolaryngology–Head and Neck Surgery Maureen Hannley Grant, the Schlager Family Practice; she is a recipient of a Brigham Care Redesign Incubator Fund Award, and the Harvard Medical School Shore Foundation Faculty Award.

Sponsorships: None.

Funding source: None.

References

24. Scangas GA, Lehmann AE, Remenschneider AK, Su BM, Shrime MG, Metson R. The value of frontal sinusotomy for...


56. Barton GR, Bankart J, Davis AC, Summerfield QA. Comparing utility scores before and after hearing-aid provision: results according to the EQ-5D, HUI3 and SF-6D. Appl Health Econ Health Policy. 2004;3:103-105.


82. Ubel PA, Hirth RA, Chernew ME, Fendrick AM. What is the price of life and why doesn’t it increase at the rate of inflation? Arch Intern Med. 2003;163:1637-1641.


