Routine Magnetic Resonance Imaging for Idiopathic Olfactory Loss
A Modeling-Based Economic Evaluation

Luke Rudmik, MD, MSc; Kristine A. Smith, MD; Zachary M. Soler, MD, MSc; Rodney J. Schlosser, MD; Timothy L. Smith, MD, MPH

**IMPORTANCE**
Idiopathic olfactory loss is a common clinical scenario encountered by otolaryngologists. While trying to allocate limited health care resources appropriately, the decision to obtain a magnetic resonance imaging (MRI) scan to investigate for a rare intracranial abnormality can be difficult.

**OBJECTIVE**
To evaluate the cost-effectiveness of ordering routine MRI in patients with idiopathic olfactory loss.

**DESIGN, SETTING, AND PARTICIPANTS**
We performed a modeling-based economic evaluation with a time horizon of less than 1 year. Patients included in the analysis had idiopathic olfactory loss defined by no preceding viral illness or head trauma and negative findings of a physical examination and nasal endoscopy.

**INTERVENTIONS**
Routine MRI vs no-imaging strategies.

**MAIN OUTCOMES AND MEASURES**
We developed a decision tree economic model from the societal perspective. Effectiveness, probability, and cost data were obtained from the published literature. Litigation rates and costs related to a missed diagnosis were obtained from the Physicians Insurers Association of America. A univariate threshold analysis and multivariate probabilistic sensitivity analysis were performed to quantify the degree of certainty in the economic conclusion of the reference case. The comparative groups included those who underwent routine MRI of the brain with contrast alone and those who underwent no brain imaging. The primary outcome was the cost per correct diagnosis of idiopathic olfactory loss.

**RESULTS**
The mean (SD) cost for the MRI strategy totaled $2400.00 ($1717.54) and was effective 100% of the time, whereas the mean (SD) cost for the no-imaging strategy totaled $86.61 ($107.40) and was effective 98% of the time. The incremental cost-effectiveness ratio for the MRI strategy compared with the no-imaging strategy was $115 669.50, which is higher than most acceptable willingness-to-pay thresholds. The threshold analysis demonstrated that when the probability of having a treatable intracranial disease process reached 7.9%, the incremental cost-effectiveness ratio for MRI vs no imaging was $24 654.38. The probabilistic sensitivity analysis demonstrated that the no-imaging strategy was the cost-effective decision with 81% certainty at a willingness-to-pay threshold of $50 000.

**CONCLUSIONS AND RELEVANCE**
This economic evaluation suggests that the most cost-effective decision is to not obtain a routine MRI scan of the brain in patients with idiopathic olfactory loss. Outcomes from this study may be used to counsel patients and aid in the decision-making process.
With fears of litigation from missing a rare diagnosis, the practice of defensive medicine is a major source of wasteful spending because defensive medicine often results in needless testing and treatments. In 2010, an estimated $55.6 billion in health care was spent on practices related to defensive medicine.\(^1\) In 2011, overtreatment and over-treatment were estimated to result in $158 billion to $226 billion of wasteful spending in the United States.\(^2\) To help curb such wasteful spending, a call has been issued to physicians to increase their consideration of cost constraint, to recognize that less care may be better care, and to use health care resources wisely.\(^3\)

Olfactory loss affects approximately 5% of the healthy population and thus represents a commonly encountered medical complaint.\(^4\) Common causes include chronic rhinosinusitis producing a conductive obstruction (ie, polyposis or edema) or olfactory damage due to chronic inflammation, a postviral upper respiratory tract infection (URTI), and head trauma.\(^5,6\) However, despite a thorough history (negative for a viral URTI or head trauma), physical examination, and nasal endoscopy, approximately 20% to 30% of cases have no clear cause and are labeled as idiopathic.\(^7,8\) Although no practice guidelines are available to direct subsequent management, patients with idiopathic olfactory loss often undergo magnetic resonance imaging (MRI) of the brain to rule out the rare potential intracranial cause, such as an olfactory groove meningioma.\(^8\) However, potentially treatable intracranial disease accounts for only 0.08% to 1.6% of all idiopathic olfactory loss,\(^9,9\) thus questioning whether obtaining a routine MRI scan is an appropriate use of limited health care resources.

The objective of this economic evaluation is to determine the cost-effectiveness of routine MRI in patients presenting with idiopathic olfactory loss. The purpose of this study was to help inform decision making for this challenging clinical scenario. The primary outcome was the incremental cost per diagnosis of idiopathic olfactory loss.

**Methods**

Approval of the University of Calgary institutional ethics review board was not required for this study. Informed patient consent was waived because all data were obtained from published studies and no individual patient data were used in the analysis. A societal payer perspective was taken for this economic evaluation. All costs are expressed in US dollars as of July 2014. The primary outcome was the cost per diagnosis of the olfactory loss. Because the time horizon for this economic evaluation was less than 1 year, the model did not require the discounting of costs and effects.

All costs and effects are presented in disaggregated and aggregated form, and incremental cost-effectiveness ratios (ICERs) are presented for the primary outcome (**Table 1**). The ICER is a commonly used equation in health economics to provide important information to decision makers who allocate resources. The ICER is calculated as the ratio of the change in costs between 2 strategies to the change in effectiveness between the 2 strategies\(^10\) as follows:

\[
\text{ICER} = \frac{\text{Cost Strategy A} - \text{Cost Strategy B}}{\text{Effectiveness Strategy A} - \text{Effectiveness Strategy B}}
\]

Therefore, the ICER provides the additional cost associated with the additional benefit of the new intervention being evaluated. The advantages of using the ICER include comparing different treatment modalities and providing valuable information to decision makers regarding the additional costs associated with a new intervention in context of the newly added benefit. The reporting of this economic evaluation follows the 2013 Consolidated Health Economic Evaluation Reporting Standards guidelines.\(^11\)

**Economic Model**

A decision tree model was constructed to simulate the clinical investigation of a patient cohort presenting with idiopathic olfactory loss. For this study, *idiopathic olfactory loss* was defined as (1) the lack of an underlying cause of the olfactory loss after a complete history, physical examination, and nasal endoscopy by an otolaryngologist and (2) no history of a preceding viral URTI or head trauma event at the time of onset.

In this model, the cost-effectiveness of the following 2 management strategies was evaluated: (1) MRI of the brain with contrast and (2) no imaging of the brain (**Figure 1**). The primary societal-based consequence of not ordering an MRI is the potential to miss a treatable related intracranial disease or neoplasm because failure to treat could result in the cost of a lawsuit along with the corresponding settlement or award. We incorporated this potential medicolegal cost into the model.

We made the following assumptions:

1. The potential lawsuit would cover a missed treatable related intracranial abnormality and not a missed untreatable or unrelated intracranial abnormality.
2. Lawsuit costs and outcomes, such as settlement and award rates, follow the US national norms.
3. Patients with an olfactory loss would receive an empirical course of systemic corticosteroid therapy; therefore, any sinus disease identified on the MRI would be managed appropriately.
4. No data defining costs associated with a delayed diagnosis of a treatable intracranial neoplasm or disease were available; therefore, we assumed that early vs late treatment costs were the same. Future studies will need to investigate this assumption to improve a longer-term model.

The model was programmed using commercially available software (TreeAge Pro 2012; TreeAge Software, Inc).

**Effectiveness Outcomes and Probabilities**

The primary effectiveness outcome was the correct diagnosis of the olfactory loss (**Table 1**). The model incorporates a correct diagnosis (\(e_{\text{correct\_diagnosis}}\)) for the MRI strategy. A correct diagnosis would involve (1) a normal MRI finding or an MRI finding that demonstrates an unrelated abnormality, thereby confirming a correct diagnosis of a true idiopathic olfactory loss, or (2) an MRI finding that demonstrates a related intracranial abnormality, regardless of being treatable or untreatable. For the no-imaging strategy, a cor-

**Table 1** Effectiveness Outcomes and Probabilities

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Effectiveness</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (MRI)</td>
<td>1</td>
<td>0.9792</td>
</tr>
<tr>
<td>B (No MRI)</td>
<td>0</td>
<td>0.0208</td>
</tr>
</tbody>
</table>

\(e_{\text{correct\_diagnosis}}\) is the potential to miss a treatable related intracranial disease or neoplasm because failure to treat could result in the cost of a lawsuit along with the corresponding settlement or award.
Routine MRI for Idiopathic Olfactory Loss

Original Investigation Research

Table 1. Reference Case Data and Sensitivity Analysis Ranges

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description of Value</th>
<th>Data*</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>p_abnormal_MRI</td>
<td>Probability of an abnormal MRI finding for idiopathic olfactory loss (68 of 122 cases)</td>
<td>0.56 (0.38-0.65)</td>
<td>Decker et al,² 2013</td>
</tr>
<tr>
<td>p_abnormal_MRI_intracranial</td>
<td>Probability that an abnormal finding of MRI ordered for idiopathic olfactory loss is an intracranial abnormality rather than a sinonasal process (30 of 68 cases)</td>
<td>0.74 (0.61-0.82)</td>
<td>Decker et al,² 2013</td>
</tr>
<tr>
<td>p_abnormal_MRI_treatable</td>
<td>Probability that when an intracranial abnormality is identified on the MRI scan, it is the cause of the olfactory loss (2 of 50 cases)</td>
<td>0.04 (0.02-0.10)</td>
<td>Decker et al,² 2013</td>
</tr>
<tr>
<td>p_treatable_intracranial</td>
<td>Probability that a patient with idiopathic olfactory loss has a treatable intracranial process (2 of 122 cases)</td>
<td>0.016 (0.01-0.04)</td>
<td>Decker et al,² 2013; Hoekman et al,² 2014</td>
</tr>
<tr>
<td>p_medicolegal_lawsuit</td>
<td>Probability of a lawsuit for missing an underlying abnormality or having a delayed treatment resulting in a settlement or an award to the patient</td>
<td>0.02 (0-0.03)</td>
<td>Localio et al,¹² 1991</td>
</tr>
<tr>
<td>p_successful_lawsuit</td>
<td>Probability of a successful lawsuit for missing an underlying abnormality or having a delayed treatment</td>
<td>0.32 (0.25-0.39)</td>
<td>Doran,¹³ 2005; Vidmar,¹⁴ 2009; Decker et al,² 2013</td>
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<thead>
<tr>
<th>Costs, $</th>
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<tbody>
<tr>
<td>c_MRI</td>
<td>Cost of an MRI of the brain with contrast</td>
<td>2400 (1000-3000)</td>
<td>Decker et al,² 2013; Hoekman et al,² 2014</td>
</tr>
<tr>
<td>c_legalfees</td>
<td>Cost of a medicolegal lawsuit</td>
<td>47 158 (25 000-100 000)</td>
<td>PIAA¹⁵ 2014</td>
</tr>
<tr>
<td>c_lawsuit_settlement</td>
<td>Median cost of all settlements and awards for a missed diagnosis or a delayed treatment from 1997 through 2003</td>
<td>958 279 (625 616-1 550 000)</td>
<td>Decker et al,² 2013</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Effects</th>
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</thead>
<tbody>
<tr>
<td>e_correct_diagnosis</td>
<td>Correct diagnosis of idiopathic olfactory loss</td>
<td>1</td>
<td>NA</td>
</tr>
<tr>
<td>e_incorrect_diagnosis</td>
<td>Missing the diagnosis of an intracranial abnormality causing olfactory loss</td>
<td>0</td>
<td>NA</td>
</tr>
</tbody>
</table>

Abbreviations: MRI, magnetic resonance imaging; NA, not applicable; PIAA, Physicians Insurers Association of America.

* Unless otherwise indicated, data are expressed as mean (95% CI).

Figure 1. Decision Tree Model to Simulate the Clinical Investigation of a Patient Cohort Presenting With Idiopathic Olfactory Loss

The model evaluates the magnetic resonance imaging (MRI) strategy vs the no-imaging strategy for this patient cohort. c_ indicates cost; e_, effect; and p_, probability (described in Table 1). # Indicates value filled by the other branch probability.

A correct diagnosis would involve (1) any scenario in which the patient had no related intracranial abnormality or (2) an untreatable related intracranial abnormality. Therefore, the only correct diagnosis that the no-imaging strategy would miss was a treatable intracranial abnormality. A treatable intracranial abnormality was defined as a disease process causing the olfactory loss that has the potential for improvement after a clinical intervention (eg, olfactory groove meningioma or multiple sclerosis). An untreatable related intracranial abnormality was defined as a disease process causing the olfactory loss that cannot be improved with a clinical intervention (eg, olfactory atrophy or remote olfactory/temporal infarct). All probabilities for this economic model were derived from 2 recent large retrospective reviews evaluating the use of MRI in the evaluation of idiopathic olfactory loss (Table 2).²⁶,⁹

Costs

The US-based cost of an MRI (c_MRI in Table 1) scan was obtained from the published literature.⁹,¹⁶ The mean cost of a medical malpractice lawsuit in 2012 was $47 158, and this cost...
was applied to all scenarios with a lawsuit (c_Legalfees in Table 1).15 The median US medical malpractice settlements were $625,616 and $682,500 for misdiagnosis and delay in treatment, respectively. For jury-awarded payments, the median costs were $975,000 and $1,550,000 for misdiagnosis and delay in treatment, respectively.9 The overall cost of the medicolegal settlement applied in this model (c_Lawsuit_settlement) was applied to all scenarios with a lawsuit (c_Legalfees in Table 1).15

Sensitivity Analysis
A univariate threshold analysis was performed to elucidate what the probability of having a treatable intracranial abnormality would have to be to make the MRI strategy a more cost-effective decision. We provide the increase in willingness-to-pay (WTP) thresholds along with the corresponding degree of certainty that the MRI is the cost-effective decision at each threshold.

We performed a multivariate probabilistic sensitivity analysis (PSA) using a Monte Carlo simulation with 15,000 scenarios. All variables in the model received standard errors based on the sample sizes and 95% CIs from the literature review (Table 1). Results from the PSA are presented as a cost-effectiveness acceptability curve. The cost-effectiveness acceptability curve is a critical measure for policy makers because it provides the degree of certainty in an economic conclusion at several different WTP thresholds.17 The degree of certainty in the economic conclusion from this model will be presented at 2 common WTP thresholds: $25,000 and $50,000 per diagnosis.18-20

Results
Reference Case
The disaggregated mean (SD) overall costs of the MRI strategy were $2,400.00 ($1717.54); for the no-imaging strategy, $866.61 ($1074.40). Mean (SD) effectiveness was 1.0 (0) and 0.98 (0.01), respectively. Overall, the most cost-effective decision was the no-imaging strategy because the ICER for MRI vs no imaging was higher than most acceptable WTP thresholds (ICER = $115,669.50 per correct diagnosis).

Univariate Threshold Analysis
The threshold analysis demonstrated that when the probability of having a treatable intracranial abnormality reached 7.9%, the ICER for MRI vs no imaging was $24,654.38. When we performed a multivariate PSA using a probability of 7.9%, the degree of certainty that the MRI strategy was now the cost-effective decision was 65% at a WTP threshold of $50,000 (Table 3).
Diagnosis. As a result, MRI is frequently ordered to prevent
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is rare (0.08% to 1.6%) that an occult treatable intracranial ab-
norality is causing the symptoms.8,9 Because patients may
have negative ramifications of a missed intracranial abnor-
mality, physicians may face litigation by missing such a rare
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Discussion

Idiopathic olfactory loss represents a challenging diagnostic
dilemma for physicians because they need to balance decreasing
the risk of missing a diagnosis by ordering routine MRI but
increasing health care expenditures with reducing health care
costs by not ordering MRI but potentially missing a rare treat-
able intracranial abnormality. Balancing both factors can be dif-
ficult, and several variables often come into play when making
this decision. This modeling-based economic evaluation took a societal perspective and included the costs of poten-
tial litigation from missing an intracranial abnormality. The pur-
pose was to perform a critical evaluation of 2 potential man-
agement strategies for patients with idiopathic olfactory loss
to assist physicians in the decision-making process. Results
from this economic evaluation suggest that not ordering rou-
tine MRI is the most cost-effective decision. The results from
this study may help with patient counseling and improve shared
decision making for patients and physicians when managing
idiopathic olfactory loss.

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have negative ramifications of a missed intracranial abnor-
mality, physicians may face litigation by missing such a rare
diagnosis. As a result, MRI is frequently ordered to prevent

missing a diagnosis, and whether this type of practice is a cost-
effective decision or the decision is driven by fear-based medi-
cine remains unclear.

Two recent studies have examined the role of MRI in the
evaluation of idiopathic olfactory loss. In 2013, Decker et al9
performed a retrospective review, including 122 patients who
underwent MRI of the brain for idiopathic olfactory loss at a
tertiary otolaryngology clinic. The outcomes demonstrated that
9 cases (7.4%) had a related intracranial finding but only 2 (1.6%)
had a treatable intracranial condition, such as an olfactory
groove meningioma. They estimated that the cost to diag-
nose a single intracranial neoplasm was $146 400 and con-
cluded that the cost of obtaining an MRI was justified in rela-
tion to the high legal costs associated with missing the
diagnosis. However, their study was not a true economic eval-
uation and did not report the incremental cost-effectiveness of
2 or more different management options. Therefore, making
definitive decisions based on their results is challenging. The
second study was published in 2014 by Hoekman et al,8 who
retrospectively reviewed idiopathic olfactory loss in 130 pa-
tients and found a much lower rate of identifying a related in-
tracranial cause (1 of 130 patients [0.08%]). These authors did
not perform a cost-effectiveness analysis, but, given the low
diagnostic yield, they concluded that the routine use of MRI
in this patient cohort might not be warranted.

Given the low incidence of identifying a treatable intracra-
nal abnormality responsible for the olfactory loss, the de-
cision to not obtain radiographic imaging is the most cost-
effective decision from a US societal perspective when

<table>
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<tr>
<th>Table 3. Outcomes From the Threshold Sensitivity Analysis</th>
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<tbody>
<tr>
<td>Probability of Having a Treatable Intracranial Abnormality, %</td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>7.9</td>
</tr>
<tr>
<td>4.6</td>
</tr>
<tr>
<td>1.6</td>
</tr>
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</table>

Abbreviations: ICER, incremental cost-effectiveness ratio; MRI, magnetic resonance imaging.

*a Indicates certainty that the MRI strategy is cost-effective at a willingness to pay of $50 000.

Multivariate PSA

The cost-effectiveness acceptability curve from the refer-
cence case PSA is displayed in Figure 2. The results dem-
strate that the no-imaging strategy is the most cost-effective
intervention, with 93% and 81% certainty in this economic con-
clusion at WTP thresholds of $25 000 and $50 000, respec-
tively.

Figure 2. Cost-effectiveness Acceptability Curve

Willingness-to-pay (WTP) thresholds with the corresponding degree of
certainty that the magnetic resonance imaging (MRI) strategy vs the no-imaging
strategy is cost-effective. The no-imaging strategy is the most cost-effective
intervention with 93% and 81% certainty in this economic conclusion at WTP
thresholds of $25 000 and $50 000, respectively (dotted line).
compared with a routine MRI strategy. This economic conclusion was supported by the PSA, which demonstrated 81% certainty at a WTP threshold of $50 000. To increase the cost-effectiveness of the MRI strategy, the pretest probability of identifying a treatable intracranial abnormality would need to be increased, thus reducing normal test findings. The threshold analysis from our study demonstrates that when the pre-MRI probability of identifying a treatable condition exceeds 8%, then the MRI strategy becomes cost-effective. Future studies should begin elucidating patient factors that increase the probability of identifying treatable intracranial causes when ordering an MRI.

After reading this economic evaluation, several factors should be considered when applying the results in real practice. First, the decision to obtain an MRI must occur in patients with an idiopathic olfactory loss, defined as having no identified cause after a full history, physical examination, and nasal endoscopy, along with no preceding URTI or head trauma at the time of onset. This point cannot be overemphasized because patients with a clear history of a preceding viral URTI or head trauma should not be categorized as having an idiopathic condition; thus, the results from this economic evaluation would not be applicable. In addition, we assumed that a patient’s dysosmia had failed to respond to an empirical trial of systemic corticosteroids, which is a relatively common treatment for potential sinonasal inflammatory causes of olfactory loss. Second, the perspective of this cost-effectiveness analysis is from the US society, and the inputted MRI costs and litigation rates may not be generalizable to other countries. Third, differentiation between a potentially treatable and an untreatable cause of the olfactory loss was important because the difference would have implications for decision making. For example, the study by Decker et al9 reported a rate of 7.4% for related intracranial causes; however, only 1.6% reflected potentially treatable disease. Because the clinical value of identifying untreatable conditions is likely minimal, our model inputted probability data to reflect treatable MRI findings, which would be the major driver of costs and effects. Fourth, the only short-term cost of missing or delaying a diagnosis of an intracranial abnormality causing the olfactory loss was the litigation costs. In reality, cost differences between early and late identification of a treatable intracranial abnormality are likely; however, no data support this assumption. Thus, we have elected to take a conservative approach and assume that no differences in cost exist. Future studies should elucidate the natural history of treatable intracranial abnormalities causing olfactory loss to help improve assumptions and develop long-term analyses. Last, the time horizon for the model was short and captured only the outcomes related to making a correct diagnosis of the olfactory loss. Ideally, the model would have assumed a longer time horizon to incorporate the long-term outcomes of diagnosing or missing the idiopathic olfactory loss. However, no data were available to generate appropriate long-term assumptions.

To generate an economic model with a longer time horizon, future studies should address several questions. First, these studies need to elucidate which patient characteristics will better predict the identification of a treatable intracranial abnormality, which would increase the MRI diagnostic yield and cost-effectiveness. This result may be achieved by comparing demographic data, risk factors, and symptoms of patient cohorts with and without treatable intracranial pathologic findings. Second, a study needs to elucidate the natural history of treatable intracranial abnormalities causing an olfactory loss. For example, do all intracranial neoplasms causing olfactory loss need to be treated, or can some cases be observed (similar to cases of vestibular schwannoma causing hearing loss)? Third, studies need to define the olfactory outcomes after treatment of intracranial abnormalities presenting with idiopathic olfactory loss because doing so would help to model the effectiveness value of identifying such conditions with the use of MRI. Last, knowing whether differences in treatment costs exist between early vs delayed identification of an intracranial abnormality causing olfactory loss would be valuable. The challenge of studying intracranial causes of olfactory loss is the relative rarity of identifying treatable disease. Based on the best available evidence, an estimated 100 patients would have to undergo MRI before 1 treatable condition is identified. This estimation makes a prospective study difficult because the study would likely need to be performed on a national level to obtain an appropriately large sample size, which is expensive and difficult to coordinate. Therefore, retrospective studies will likely be the ideal design to begin addressing some of the future studies outlined in this report and improve data on the topic of idiopathic olfactory loss and the role of MRI.

Conclusions

This economic evaluation studied the cost-effectiveness of obtaining a routine MRI scan in patients with an idiopathic olfactory loss. In patients who have no identifiable cause after a thorough history and who have negative findings for preceding viral illness or head trauma and after physical examination and nasal endoscopy, the results have demonstrated that obtaining no additional imaging is the most cost-effective decision. Future studies should work to identify high-risk factors for a treatable intracranial abnormality and elucidate the natural history and treatment outcomes of intracranial disease causing olfactory loss to improve the development of long-term economic models.
Routine MRI for Idiopathic Olfactory Loss

Original Investigation Research

Statistical analysis: Rudmik.
Study supervision: K. A. Smith, Soler, Schlosser, T. L. Smith.

Conflict of Interest Disclosures: Dr Soler has received support from a grant from the National Institute on Deafness and Other Communication Disorders, National Institutes of Health (NIDCD/NIH), and served as a consultant for Brainlab. Dr Schlosser has served as a consultant for Brainlab, Olympus, and United Allergy and received grant support from Medtronic, Arthrocare, Intersect ENT Inc, Optinose, and NeilMed. Dr T. L. Smith has served as a consultant for Intersect ENT Inc and received grant support from the NIDCD/NIH. No other disclosures were reported for the other contributing authors.

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