Cost-effectiveness Analysis of Endoscopic Sphenopalatine Artery Ligation vs Arterial Embolization for Intractable Epistaxis

Luke Rudmik, MD, MSc; Randy Leung, MD

IMPORTANCE Intractable epistaxis is a common otolaryngology emergency. Transnasal endoscopic sphenopalatine artery ligation (TESPAL) and endovascular arterial embolization both provide excellent success rates, and therefore the decision to choose one over the other can be challenging.

OBJECTIVE To aid in decision making by evaluating the cost-effectiveness of TESPAL vs endovascular arterial embolization for intractable epistaxis.

DESIGN, SETTING, AND PARTICIPANTS Economic evaluation using a decision tree model with a 14-day time horizon for emergency department consultations for patients with intractable epistaxis defined as persistent bleeding despite bilateral anterior nasal packing. The economic perspective was the health care third-party payer. Effectiveness and probability data were obtained from the published medical literature. Costs were obtained from the published literature, the Centers for Medicare & Medicaid Services database, and the Healthcare Cost and Utilization Project database. Multiple sensitivity analyses were performed, including a probabilistic sensitivity analysis. Comparative treatment groups were (1) TESPAL and (2) embolization.

INTERVENTIONS TESPAL and endovascular arterial embolization.

MAIN OUTCOME AND MEASURES The primary outcome was the incremental cost-effectiveness ratio (ICER) for successful control of epistaxis.

RESULTS The reference case demonstrated that the embolization strategy was more effective but more costly compared with the TESPAL strategy: $22 324.70 per 0.70 effectiveness compared with $12 484.14 per 0.68 of effectiveness, respectively. The embolization vs TESPAL ICER was $492 028, which is higher than any willingness to pay (WTP), suggesting that TESPAL is the cost-effective decision. The sensitivity analysis demonstrated a 77.6% and 73.7% certainty that the TESPAL strategy is cost-effective at WTP thresholds of $10 000 and $50 000, respectively.

CONCLUSIONS AND RELEVANCE Results from this economic evaluation suggest that when both TESPAL and arterial embolization are viable options (based on patient and institutional factors), TESPAL is the more cost-effective treatment strategy for patients with intractable epistaxis.

Author Affiliations: Division of Otolaryngology, Department of Surgery, University of Calgary, Calgary, Alberta, Canada (Rudmik); Department of Otolaryngology–Head and Neck Surgery, University of Toronto, Royal Victoria Regional Health Centre, Barrie, Ontario, Canada (Leung).

Corresponding Author: Luke Rudmik, MD, MSc, Division of Otolaryngology–Head and Neck Surgery, Department of Surgery, University of Calgary, Foothills Medical Centre, South Tower, Ste 602, 1403 29th St NW, Calgary, AB T2N 2T9, Canada (lukerudmik@gmail.com).
Intractable epistaxis is a common otolaryngology emergency that develops when the first-line attempts at cauterization and anterior nasal packs fail to control nasal bleeding. The traditional treatment strategy of posterior nasal packing has been largely replaced by the more effective and less morbid techniques of transnasal endoscopic sphenopalatine artery ligation (TESPAL)\textsuperscript{1-3} and endovascular arterial embolization.\textsuperscript{4-6} Furthermore, a recent study by Dedhia et al\textsuperscript{7} suggested that TESPAL is the most cost-effective strategy compared with posterior nasal packing. The success rates for both TESPAL and embolization is estimated to be greater than 90%, and therefore the decision to choose one modality over another can be challenging.

Advantages of TESPAL over embolization include reduced risk of major complications (ie, stroke, blindness, and soft-tissue ischemia), direct visualization with targeted control of the bleeding site, potential diagnosis of rare causes of bleeding (eg, neoplasms), potential to perform a concurrent anterior ethmoid artery ligation if required (either open or endoscopically), and a reported lower health care cost.\textsuperscript{8} The primary advantages of endovascular arterial embolization over TESPAL include the ability to perform the procedure under local anesthetic and thus avoid the potential risks of a general anesthetic, the ability to occlude other branches of the external carotid artery that may be contributing (eg, facial artery), the ability to diagnose vascular abnormalities, and to cause potentially less trauma to the nasal mucosa by avoiding surgical manipulation.\textsuperscript{8}

During the treatment of intractable epistaxis, physicians often consider several factors, such as potential adverse events, institutional and surgeon expertise, and patient comorbidities; however, the cost-effectiveness of TESPAL and embolization in this patient cohort should also be considered in the decision-making process.\textsuperscript{8} The purpose of this economic evaluation is to perform a decision tree analysis to compare the cost-effectiveness of TESPAL vs arterial embolization for intractable epistaxis. Results from this study may help improve the decision-making process for this challenging clinical scenario.

Methods

This was a modeling-based economic evaluation using a decision tree analysis with a time horizon of 2 weeks. It simulated the treatment of a patient with intractable epistaxis using 1 of the following 2 comparative interventions: (1) TESPAL and (2) arterial embolization (Figure 1). Intractable epistaxis was defined as nasal bleeding, either anteriorly or posteriorly, that continues despite bilateral anterior nasal packing. A time horizon of 2 weeks was chosen because recurrences in this time period are thought to be related to a failure of the initial procedure.\textsuperscript{3} The primary outcome was the cost per successful control of epistaxis. All costs and effects are presented in disaggregated and aggregated form, and the primary outcome is presented as the incremental cost-effectiveness ratio (ICER) between the 2 interventions. The ICER is a commonly used equation in health economics to provide important information to resource allocation decision makers. It is the ratio of change in costs between 2 strategies to the change in effectiveness between the 2 strategies: (Cost Strategy A – Cost Strategy B)/(Effectiveness Strategy A – Effectiveness Strategy B).\textsuperscript{9} Therefore, the ICER provides the additional cost associated with the additional benefit of the new intervention being evaluated. The advantages of using the ICER is that it can be used to compare the multiple different treatment modalities and provides helpful information to decision makers regarding the additional costs associated with a new intervention in context of the newly added benefit.

No discounting was applied because the time horizon was less than 1 year. Models are simplified frameworks of complex real-life processes; therefore, most models require assumptions in order to evaluate the question being asked. The Box outlines the assumptions incorporated into this model. The model was programmed by using TreeAge Pro 2012 software (TreeAge Pro Inc).

Effectiveness Values

Effectiveness was defined as the success of controlling the intractable epistaxis. To incorporate the differences between controlling epistaxis with or without minor complications, we defined success with no complications to have an effect value of 1 (e_Success_no_complication) and success with minor complication (e_Success_minor_complication) to have an effect value of 0.5. All scenarios in which the patient experienced a major or permanent complication were assigned an effect value of 0 (e_failure) (Table 1).

Probabilities

Probabilities used to move patients through the various clinical branches were extracted from the medical literature. The literature search involved querying Ovid MEDLINE (1947 through August 2012), and 2 separate searches were performed: 1 for TESPAL and 1 for embolization. The TESPAL search included the terms “epistaxis,” “endoscopic,” and “sphenopalatine.” The embolization search included the terms “epistaxis” and “embolization.” To input the highest level of evidence into the model,\textsuperscript{10} the search focused on identifying systematic reviews and randomized clinical trials (RCTs). The reference lists of all studies were examined to ensure that all relevant studies were captured. Data were extracted from the reviews, and the probabilities are presented in Table 1.

Costs

The cost perspective of this economic evaluation is from the US third-party payer, and all monetary values are presented in 2014 US dollars (USD). The costs for TESPAL (c_SPALigation) and embolization (c_Embolization) were obtained from a 2013 study by Villwock and Goyal\textsuperscript{11} that reviewed the Nationwide Inpatient Sample database to identify over 4662 cases of TESPAL and embolization between 2008 and 2010. The overall mean (SD) costs for early TESPAL and embolization were $9746 ($10 219) and $20 305 ($13 124), respectively. These costs represent the mean total inpatient hospital encounter for patients treated with each of these modalities. The costs for a major episode of rebleeding following either TESPAL (c_SPA_major_rebleed) or embolization (c_Embolization_rebleed) were assigned the isolated procedural cost rather than assigning an additional total inpatient cost to the pathway. The isolated procedural cost for TESPAL was estimated to be $6000 (range,
The costs for a “major transient” and “permanent” complication following embolization were estimated from the Healthcare Cost and Utilization Project database produced by the US Agency for Healthcare Research and Quality. A major transient complication (c_Embo_major_transient) was estimated using the diagnosis-related group (DRG) code for transient ischemia (DRG code 69), and the mean cost was $5916. The cost of permanent complication (c_Embo_permanent) was estimated from the DRG for intracranial hemorrhage or cerebral infarction (DRG code 66), and the mean cost was $18,538 (Table 1). The range of costs for the permanent complication following embolization was obtained from a study by Payne et al, which quantified the long-term costs of stroke.

For this model, the postoperative transient complication following TESPAL (c_SPA_postop_transient) included an acute bacterial rhinosinusitis and sinonasal crusting with adhesions. Postoperative complication costs were obtained from the Centers for Medicare & Medicaid Services Physician Fee Schedule using the corresponding Current Procedural Terminology (CPT) codes for an office visit with endoscopic debridement. All individual cost variables are presented in Table 1.

### Sensitivity Analysis
A threshold analysis was performed to determine what the cost of either TESPAL or embolization would have to be to make the opposing strategy become the cost-effective intervention.
To take into account the inherent uncertainty with the data entered into the model, a multivariate probabilistic sensitivity analysis (PSA) using a Monte Carlo simulation with 15,000 scenarios was performed. All variables in the model received standard errors based on data and clinical ranges from the literature review. Results are presented in both a cost-effectiveness acceptability curve (CEAC) and ICER scatterplot.

The CEAC is a graph that visually represents the level of uncertainty in an economic evaluation at various willingness-to-pay (WTP) thresholds.\(^{19}\) It is a very important outcome for policy makers because it provides the probability that they are making the cost-effective decision to implement a certain intervention at several different WTP thresholds. The ICER scatterplot is a technique used to visually demonstrate the cost-effectiveness of all the different ICERs generated from the 15,000 iterations of the PSA. The ICERs are plotted onto the cost-effectiveness plane that is divided into 4 quadrants.\(^{20}\) On the one hand, quadrant 2 ICERs are both cheaper and more effective and therefore the dominant intervention. On the other hand, quadrant 4 ICERs are more expensive and less effective and therefore are considered to be dominated and are typically rejected. Decisions to accept the alternative intervention in quadrants 1 and 3 depend on the maximum ICER for which policy makers are willing to accept and lie to the right of the WTP threshold line.

## Results

### Reference Case

The reference case modeled a patient cohort with intractable epistaxis treated with either TESPAL or embolization with a time horizon of 2 weeks to incorporate failures after discharge from the hospital. The TESPAL strategy was cheaper but slightly less effective compared with embolization: $12,484.14 per 0.68 of effectiveness compared with $22,324.70 per 0.70 of effectiveness (Table 2). The ICER for embolization vs TESPAL is $492,028 per successful control of epistaxis. Because most countries do not accept an ICER greater than $50,000 per effect, the results from the reference case suggest that the added cost of embolization does not justify the mild increase in effectiveness. Therefore, the TESPAL strategy is the cost-effective intervention.

### Sensitivity Analysis

#### Threshold Analysis

Using a WTP threshold of $50,000, the threshold analysis demonstrates that embolization becomes the cost-effective choice if the overall procedure cost is reduced to $10,221 per case while keeping the overall cost of TESPAL at the reference price of $9,746 per case. In addition, embolization would become the cost-effective strategy if the overall TESPAL procedural cost was raised to $19,803 per case while keeping the overall embolization cost at the reference of $20,305 per case.

#### Multivariate Analysis

When graphing the multivariate PSA using the CEAC, the PSA demonstrates that the degrees of certainty that the TESPAL strategy is the cost-effective decision are 77.6% and 73.7% at WTP thresholds of $10,000 and $50,000, respectively (Figure 2). The ICER scatterplot demonstrates that most of the TESPAL vs embolization ICERs lie within quadrant 2 (thus are dominant—less costly and more effective) or below the $50,000 WTP line in quadrant 3 (thus have a cost-effective level of less costly and less effective) (Figure 3).

## Discussion

This economic evaluation compared the cost-effectiveness of TESPAL vs endovascular arterial embolization for the treatment of intractable epistaxis. A decision tree analysis with a time horizon of 2 weeks was used to incorporate potential post-procedural outcomes. The outcomes from the reference case demonstrated that the TESPAL strategy was the cost-effective choice, and the multivariate sensitivity analysis confirmed that there was a greater than 74% certainty that this economic conclusion was correct. The threshold analysis demonstrated that the following 2 changes in procedural costs would have to occur before the embolization strategy would be the cost-effective decision: (1) the cost of TESPAL would have to increase from the current cost of $9,746 to $19,803 per case, and (2) the cost of embolization would have to decrease from the current cost of $20,305 to $10,221 per case.

Otolaryngologists are commonly consulted to treat intractable epistaxis in the emergency department. The decision to pursue either TESPAL or embolization can be challenging because both procedures have excellent success rates, exceed-
Intractable epistaxis often occurs in patients with several comorbidities (eg, receiving anticoagulation drugs [warfarin or antiplatelet therapy] or having poorly controlled hypertension), and the TESPAL or embolization procedures are complex, requiring specialized equipment and clinical expertise to perform. These factors often make the decision to pursue either TESPAL or embolization dependent on patient and institutional factors. However, it is common to encounter clinical situations in which both treatment options are viable; in this case, it would be most appropriate to make a decision based on the most cost-effective choice to optimize the utilization of limited health care resources. This was the impetus behind performing this economic evaluation, and the results suggest that TESPAL is the cost-effective decision when both treatment options are viable.

The results of this economic evaluation are strengthened by the use of current health care costs (2014 USD), use of a 2-week time horizon to capture late recurrences, and the inclusion of a robust multivariate sensitivity analysis with incorporation of evidence-based variations in model inputs. Despite these methodologic strengths, there are several limitations that should be considered when interpreting these

### Table 1. Reference Case Data and Sensitivity Ranges

<table>
<thead>
<tr>
<th>Source</th>
<th>Variable</th>
<th>Description</th>
<th>Value (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probabilities</td>
<td>p_{SPA_major_rebleed}</td>
<td>Probability of developing a major episode of early rebleeding after SPA ligation requiring packing and embolization</td>
<td>0.005 (0.003-0.100)</td>
</tr>
<tr>
<td></td>
<td>p_{SPA_minor_rebleed}</td>
<td>Probability of developing a minor episode of rebleeding after SPA ligation requiring re-packing</td>
<td>0.17 (0.15-0.20)</td>
</tr>
<tr>
<td>Snyderman et al</td>
<td>p_{SPA_postop_transient}</td>
<td>Probability of developing a transient postop complication</td>
<td>0.34 (0.03-0.40)</td>
</tr>
<tr>
<td>Kumar et al</td>
<td>p_{SPA_recurrence}</td>
<td>Probability of developing a recurrence of epistaxis within 2 weeks after SPA ligation</td>
<td>0.12 (0.02-0.15)</td>
</tr>
<tr>
<td>Christensen et al</td>
<td>p_{Embo_recurrence}</td>
<td>Probability that of developing a recurrence of epistaxis within 2 weeks after the packs are removed</td>
<td>0.12 (0.02-0.15)</td>
</tr>
<tr>
<td>Willems et al</td>
<td>p_{Embo_major_transient}</td>
<td>Probability of developing a major transient complication</td>
<td>0.005 (0.002-0.100)</td>
</tr>
<tr>
<td>Willems et al</td>
<td>p_{Embo_minor_transient}</td>
<td>Probability of developing a minor transient complication</td>
<td>0.37 (0.25-0.50)</td>
</tr>
<tr>
<td>Willems et al</td>
<td>p_{EmboPermanent}</td>
<td>Probability of developing a permanent major complication</td>
<td>0.100 (0.005-0.200)</td>
</tr>
</tbody>
</table>

### Table 2. Disaggregated Costs and Effect Outcomes for a Reference Case

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Cost, $ (SD)</th>
<th>Effectiveness (SD)</th>
<th>ICER (Cost per Successful Control of Epistaxis), $</th>
</tr>
</thead>
<tbody>
<tr>
<td>TESPAL</td>
<td>12 484.14 (10 670)</td>
<td>0.68 (0.06)</td>
<td>TESPAL vs Embolization = –492 028</td>
</tr>
<tr>
<td>Embolization</td>
<td>22 324.70 (13 106.14)</td>
<td>0.70 (0.07)</td>
<td>Embolization vs TESPAL = 492 028</td>
</tr>
</tbody>
</table>

Abbreviations: ICER, incremental cost-effectiveness ratio; TESPAL, transnasal endoscopic sphenopalatine artery ligation.
results. First, the primary outcome of “cost per successful control of the epistaxis” is not generalizable to other common economic evaluation outcomes, such as cost per quality-adjusted life-year or cost per life-year saved. This limits the ability of policy makers to apply the results from this economic evaluation to shift resources away from another intervention toward TESPAL. However, the primary outcome was appropriate to compare TESPAL with embolization and is specific for treatment of epistaxis. We hope future economic evaluations studying epistaxis-related interventions will use this outcome to improve generalizability during comparisons. Second, the effect values of “1 for success without complication,” “0.5 for success with minor complication, and “0 for failure” were arbitrary but meant to capture the reduced patient preference for developing minor and major complications during their treatment. To ensure that the effect values provided for our reference case did not influence the economic conclusions, we performed a sensitivity analysis to change these parameters, and there was no change. Third, to our knowledge, there have been no large RCTs comparing TESPAL and embolization; therefore, there will inherently be larger degrees of data uncertainty in the data entered into this model because it was derived from nonrandomized prospective or retrospective studies. To overcome this limitation, we provided the large ranges from all model parameters in order for the sensitivity analysis to account for the variability. A future economic evaluation performed alongside an RCT evaluating these 2 interventions would improve the accuracy of the economic conclusion from our study.

Finally, this economic model considered patients with intractable epistaxis to be a single cohort when in reality there are several patient factors that result in outcome variations. For example, patients prescribed anticoagulation drugs or patients with thrombocytopenia have been shown to have a higher rate of rebleeding following TESPAL. To refine the outcomes from this economic evaluation, a future risk analysis could incorporate specific patient factors to determine when embolization should be considered over TESPAL.

**Conclusions**

Intractable epistaxis is a common otolaryngology emergency, and the decision to choose either TESPAL or embolization can be challenging. The outcomes from this decision tree economic evaluation suggest that when both TESPAL and arterial embolization are viable options, TESPAL is the more cost-effective treatment strategy for patients with intractable epistaxis. Future studies are needed to elucidate which patient cohorts would be best treated with arterial embolization compared with TESPAL.
ARTICLE INFORMATION
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Study concept and design: Both authors.
Acquisition, analysis, or interpretation of data: Both authors.
Drafting of the manuscript: Rudmik.
Critical revision of the manuscript for important intellectual content: Both authors.
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Study supervision: Leung.

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REFERENCES