Cost Benefit and Utility Decision Analysis of Turbinoplasty with Adenotonsillectomy for Pediatric Sleep-Disordered Breathing

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Abstract

Objectives. Use decision analysis techniques to assess the potential utility gains/losses and costs of adding bilateral inferior turbinoplasty to tonsillectomy/adenoidectomy (T/A) for the treatment of obstructive sleep-disordered breathing (oSDB) in children. Use sensitivity analysis to explore the key variables in the scenario.

Study Design. Cost-utility decision analysis model.

Setting. Hypothetical cohort.

Subjects and Methods. Computer software (TreeAge Software, Williamstown, Massachusetts) was used to construct a decision analysis model. The model included the possibility of postoperative complications and persistent oSDB after surgery. Baseline clinical and quality-adjusted life year (QALY) parameters were estimated using published data. Cost data were estimated from Centers for Medicare and Medicaid 2018 databases (www.cms.gov). Sensitivity analyses were completed to assess for key model parameters.

Results. The utility analysis of the baseline model favored the addition of turbinoplasty (0.8890 vs 0.8875 overall utility) assuming turbinate hypertrophy was present. Sensitivity analysis indicated the treatment success increase (%) provided by concurrent turbinoplasty was the key parameter in the model. A treatment success increase of 3% of turbinoplasty was the threshold where concurrent turbinoplasty was favored over T/A alone. The incremental cost-effectiveness ratio (ICER) of $27,333/QALY for the baseline model was favorable to the willingness-to-pay threshold of $50,000 to $100,000/QALY for industrialized nations.

Conclusions. The addition of turbinoplasty for children with turbinate hypertrophy to T/A for the treatment of pediatric oSDB is beneficial from both a utility and cost-benefit analysis standpoint even if the benefits of turbinoplasty are relatively modest.

Keywords
pediatric sleep-disordered breathing, turbinoplasty, decision analysis, cost-effective analysis, incremental cost-effectiveness ratio

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Tonsillectomy/adenoidectomy (T/A) is the first-line treatment for obstructive sleep apnea (OSA) for otherwise healthy children over 2 years old¹ and is considered the surgical standard of care.² The removal of enlarged lymphoid tissue removes a source of upper airway obstruction, improving airflow and sleep quality. In this patient population, T/A is curative for OSA in approximately 80% of cases and improves quality of life compared to watchful waiting.³,⁴ Bilateral inferior turbinate hypertrophy represents another potential contributing etiology for nighttime breathing obstruction, especially in the pediatric population.⁵,⁶ Chronic nasal obstruction in children induces mouth breathing in children, which may worsen obstructive sleep-disordered breathing (oSDB) as well as further detract from quality of life. Although not studied extensively, bilateral inferior turbinoplasty has been shown to be an effective, safe procedure in children that can potentially improve nasal congestion⁷ and snoring,⁸ and it does not significantly increase complication rates when performed concurrently with T/A.⁹,¹⁰ Tonsillectomy/adenoidectomy with bilateral inferior turbinoplasty (T/A-BITR) has been demonstrated to significantly improve objective sleep parameters and subjective quality-of-life scores compared to T/A alone in the pediatric population.¹¹

Decision analysis can help further explore the potential success of T/A-BITR compared to the current standard of...
In a decision analysis study, a decision tree is plotted starting from a choice with alternative treatment options along with their relevant outcomes, including any unique complications (e.g., potential epistaxis with turbinoplasty). The value and cost of each alternate in the decision tree are determined by multiplying the likelihood of that outcome with the value/cost of said outcome. Decision analysis techniques can assess which parameters are most important and drive key model outcomes. The objective of this study was to examine the utility and cost-effective outcomes of T/A-BITR vs T/A alone using a cost-benefit decision analysis model with baseline parameter values taken from the published biomedical literature.

**Methods**

This study used only published data and was therefore exempted from institutional review board at our respective institutions. A thorough literature was conducted (MEDLINE, PubMed, Cochrane Databases) to determine initial model parameters and appropriate complication ranges for postoperative tonsil hemorrhage and epistaxis. All baseline parameter values in our model and the range used for subsequent sensitivity analysis are outlined in Table 1.

A decision analysis model was created using TreeAge Pro (TreeAge Software, Williamstown, Massachusetts) comparing the total cost, total utility, and cost-effectiveness measures between T/A and T/A-BITR for treatment of pediatric oSDB. In this model, patients underwent either T/A alone or T/A-BITR and could have either an uncomplicated recovery or a tonsil bleed, an episode of epistaxis, or both. Clinical end states were resolution or persistence of oSDB. From literature values, we set a success rate of 85% in resolving oSDB for T/A in our baseline model, with a range of 60% to 95%. For T/A-BITR, the baseline success rate was 88%, with a range of 61% to 98%.

For simplicity, several assumptions were made during model development: (1) pediatric (up to age 18 years) patient population meeting criteria for T/A for treatment of oSDB; (2) bilateral inferior turbinoplasty performed only when there was visually confirmed inferior turbinate hypertrophy; (3) surgeries performed at an outpatient facility on a same-day basis; (4) hemorrhage, whether from the throat or nose, requiring a return to the operating room (OR) for control; and (5) patients with only 1 significant complication event per surgical site (i.e., no repeat tonsil bleeds, but a tonsil bleed and a separate epistaxis episode were possible).

For the purposes of the utility analysis, the range of possible health states ranged from 0 (dead) to 1 (perfect health). Every surgery, complication, and disease state had a relative utility value that detracted from a score of 1. This approach has been used in previously published studies. These utility values were reviewed for appropriateness and consensus achieved by 3 other otolaryngologists not involved with this study. This model’s anchor states ranged from a high of 0.95 (best outcome; T/A without complication and cure of oSDB) to a low of 0.39 (worst outcome; T/A-BITR complicated by tonsil bleed and epistaxis with persistent oSDB). The utility values assigned for each state were based on a commonsense approach to what a typical patient/parent would consider reasonable. Utility values were appropriately adjusted for cases needing additional operations (e.g., return to OR for management of a complication) to mimic real-life inconveniences for having multiple surgeries.

For the cost outcome analysis, a monetary cost for each surgical outcome was calculated to allow a direct comparison of total cost for T/A vs T/A-BITR. Using Centers
for Medicare & Medicaid Services (CMS) data (2017 Physician Fee Schedule\(^{16}\) and 2018 Ambulatory Surgery Center Payment Rates\(^{17}\)), the total costs for intervention were tallied for pediatric adenotonsillectomy (T/A) vs tonsillectomy/adenoidectomy with bilateral inferior turbinate ablation (T/A-BITR). Values and probabilities are listed in Table 1. Cost data extrapolated from 2017 and 2018 Centers for Medicare & Medicaid Services (CMS) reimbursement scales.

**Results**

**Utility**

The complete model is shown in Figure 1. T/A-BITR was found to have overall higher utility compared to T/A (0.8890, 0.8875) in the baseline model using the best available estimate of parameter values extracted from published literature. Extensive sensitivity analysis was performed to assess the key parameters driving model results. This analysis revealed that the rate of additional surgical success provided by turbinoplasty to adenotonsillectomy was a key parameter in determining model results. The overall cumulative utility for T/A-BITR and T/A was equal at a break-even increase in surgical success rate of 3% provided by concurrent turbinoplasty (Figure 2). Success increase rates above this threshold provided by turbinoplasty increasingly favored T/A-BITR over T/A.

**Cost**

The cost analysis revealed that T/A-BITR ($3268) was the overall more expensive option compared to T/A ($3227). This dollar amount factored in additional cost associated with the extra procedure (including any additional equipment), potential cost of epistaxis, and potential total reduced cost of persistent oSDB given increased chance for cure. Sensitivity analysis was then used to determine the most influential parameters within the cost model, which were in decreasing order as follows: the probability of T/A alone being curative, the cost of persistent OSA, and the rate of increased cure rate of OSA from concurrent turbinoplasty. The total cumulative costs of T/A and T/A-BITR were even at an increased surgical success rate of 4% provided by concurrent turbinoplasty (Figure 3).

**Cost-Effectiveness**

Although T/A-BITR had a higher overall total cost, its associated incremental cost-effectiveness ratio (ICER) was calculated to be $27,333 per quality-adjusted life year (QALY) using best estimate, baseline model parameters. This was calculated by dividing the increased cost by the increased utility (= $3268 – $3227) / (0.8890 – 0.8875).

**Discussion**

This study used decision analysis modeling techniques to compare the relative utility and cost outcomes between the current surgical standard of care to treat pediatric oSDB with T/A to an alternative surgery of T/A-BITR. Our goal was to determine whether a concurrent turbinoplasty, in the appropriate patient (ie, one with turbinate hypertrophy), would provide added overall utility when possible complications were fully considered and, if so, whether it would do so in a cost-effective manner. Each path in our model represented a unique potential patient result for a child with oSDB meeting criteria for surgical excision.
Figure 3. One-way sensitivity analysis of the increase in surgical success from concurrent turbino-oplasty (pTurbBoost) impacting total cost. Tonsillectomy/adenoidectomy (T/A) is the less expensive option until a rate of 4%. Beyond this, tonsillectomy/adenoidectomy with bilateral inferior turbino-oplasty (T/A-BITR) has less total cumulative cost.

Not unexpectedly, T/A-BITR had higher overall total cost. This is inherent to having an additional procedure as well as the potential for another complication and its associated costs. Notably, T/A-BITR’s overall total cost was only $41 higher than that of T/A’s. This relatively modest increase in cost is likely due to multiple factors: (1) additional turbino-oplasty is relatively inexpensive, costing on average an additional $170 when added as a second procedure; (2) the low incidence of complications, so minimal additional costs for treating epistaxis; and (3) the cost-savings achieved from resolution of oSDB—although the increased success rate may be modest, the cost of untreated oSDB is high. Children with untreated oSDB have been reported to have a more than 200% increase in health care utilization with a significantly higher number of hospitalization days, emergency department (ED) visits, and medication prescriptions.

T/A-BITR also had the higher overall utility. The subsequent sensitivity analysis results indicate that the potential increase in OSA cure rate from the addition of concurrent turbino-oplasty is the key driver of this gain in utility. Interestingly, only a modest gain in surgical success rate of 3% to 4% from concurrent turbino-oplasty is needed for this procedure to become dominant in terms of utility and cost. This determined range of 3% to 4% seems to be well within the likely increased benefit in surgical success provided by concurrent turbino-oplasty demonstrated in the limited available published literature investigating T/A with concurrent turbino-oplasty.

The ICER is a value used by health economists and policy makers to assess the cost-effectiveness of a health care intervention. It is calculated dividing the difference in cost between 2 interventions by the difference in their effect (C₁−C₀/E₁−E₀).19 An intervention that delivers increased patient utility or benefit at a lower cost is considered universally dominant over its alternative. The most common scenario, however, is an intervention providing increased clinical result at a higher cost. The ICER can then be used to assess the ‘‘worthiness’’ of a new intervention given a society’s limited resources. For example, the United Kingdom’s National Institute for Health and Care Excellence sets an explicit (but not absolute) threshold of £20,000 to £30,000 when assessing whether to reject or accept new health care technologies.20 The United States currently does not currently integrate ICER into policy, but it is generally accepted that a value under $50,000/QALY is cost-effective.21 According to our model, the ICER for a concurrent turbino-oplasty was $27,333 under this societal benchmark (often called the willingness-to-pay threshold). Therefore, even if turbino-oplasty provides a relatively small benefit, it is cost-effective.

Limitations to our study must be acknowledged. As with all modeling studies, accuracy and validity depend on the quality of input parameters (eg, cost, complication rates). However, a wide range of published literature was reviewed to determine the best estimate baseline parameter values, such as bleeding and cure rates to minimize any bias that could arise from overrelaxion on a single source. Secondary sensitivity analyses were then employed to verify that our findings held true across a wide range of parameter values, reflecting the range published in the literature. An additional limitation is that cost is difficult to capture accurately, given the range of values cited and variability based on patient insurance status, geographic location, and individual hospital or practice billing methods. This model sought to compare best estimate relative costs. This model simplified costs by using a single payment databank (CMS 2018) and by doing so was hopefully able to obtain accurately comparative values and achieve the goals of the study. However, due to these simplifications, this model may not perfectly capture the relative total societal costs (eg, cost of patients needing overnight observation).

This model also made several assumptions, such as requiring OR for control of any bleeding (oropharyngeal or nasal). In practice, some of these patients are simply observed—whether for a number of hours in the ED or via formal readmission. Unfortunately, literature on the precise percentages of bleeds requiring cauterrization vs observation is sparse. To compare as accurately as possible, costs for the most expensive case for either bleed (return to the OR) were used for all postoperative hemorrhage. ED admission for dehydration, another relatively common scenario post-T/A, was also not included in this model; however, this should not affect the relative cost comparison between T/A and T/A-BITR, as it would have occurred in equal amounts for both populations.

In our model, T/A-BITR proved the method with higher utility but at a higher total cost. Ultimately, it was cost-effective on a societal level compared to T/A alone. However, one must remember that results from this decision model are designed for population-level outcomes assessment and may not apply to every individual patient. Clinical
judgment and individual preferences still remain a priority when assessing whether a concurrent turbinoplasty may be appropriate for each patient. In addition, prospective randomized studies comparing T/A to T/A-BITR would always be preferred over modeling techniques to determine optimal surgical outcomes, yet to date, these data do not exist in the published literature. In the absence of these data, decision analysis modeling may provide the clinician with a loose guide of expected outcomes.

Conclusion

In a population-level model using best-estimate parameter values extracted from the published literature, T/A-BITR may be superior to T/A in terms of cost-effectiveness and overall total utility when performed in pediatric patients with turbinate hypertrophy meeting criteria for T/A to treat ODB. The increase in OSA cure rate obtained by concurrent turbinoplasty is a key determinant driving this result. The model with sensitivity analysis demonstrates that only modest improvements in success from concurrent turbinoplasty are needed for this procedure to become favored over T/A alone.

Author Contributions

Grace Baik, conception/design, data analysis, data interpretation, manuscript drafting and revision, final approval to version to be published, agree to be accountable for all aspects of work; Scott E. Brietzke, conception/design, data analysis, data interpretation, manuscript drafting and revision, final approval to version to be published, agree to be accountable for all aspects of work.

Disclosures

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