Comparing Upper Airway Stimulation to Transoral Robotic Base of Tongue Resection for Treatment of Obstructive Sleep Apnea

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Objectives: Transoral robotic surgery (TORS) and upper airway stimulation (UAS) are modalities for treating tongue base obstruction contributing to obstructive sleep apnea (OSA). We aim to compare patients with OSA undergoing UAS to those undergoing TORS.

Methods: We retrospectively reviewed patients treated with TORS and UAS using the senior authors’ surgical database. We evaluated demographic, preoperative polysomnography (PSG), postoperative PSG, complication, hospital length of stay, and readmission data to compare the two cohorts.

Results: Seventy-six patients underwent UAS. This included 50 men and 26 women. The mean age and body mass index were 61.92 and 29.38. The mean pre- versus postoperative apnea hypopnea index (AHI) and O2 nadir were 36.64 versus 7.20 and 80.27% versus 86.77%, respectively. The rate of surgical success and postoperative AHI less than 15 and 5 were 86.84%, 89.47%, and 59.21. All patients underwent ambulatory surgery, and no one was readmitted.Twenty-four patients underwent TORS. This included 20 men and four women with a mean age and body mass index BMI of 46.42 and 29.63. The mean pre- versus postoperative AHI and O2 nadir were 35.70 versus 20.05 and 80.50% versus 84.10%, respectfully. The rate of surgical success and postoperative AHI less than 15 and 5 were 54.17%, 50.00%, and 20.83%. The mean length of stay was 1.33 days, and four patients were readmitted.

We found significant differences in age, postoperative AHI and O2 nadir, surgical success and postoperative AHI less than 15 and 5, length of stay, and rate of readmission.

Conclusions: UAS is successful in treating OSA showing improved outcomes, length of stay, and readmission compared to TORS.

Key Words: Obstructive sleep apnea, surgical treatment of obstructive sleep apnea, sleep apnea.

Level of Evidence: 3

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INTRODUCTION

The feasibility of transoral robotic surgery (TORS) was first explored by Weinstein et al. in a canine model in 2005.1 Since that publication, the practicality and safety have been established for the treatment of oropharyngeal and laryngeal pathology in human patients, and the technology has been adopted by many tertiary care otolaryngology practices.2–4 TORS was approved by the Food and Drug Administration (FDA) for the treatment of T1 and T2 oropharyngeal cancer in December 2009. In 2010, Vicini et al. published the first study investigating the use of TORS for the treatment of obstructive sleep apnea (OSA). They evaluated 10 patients and concluded that those with tongue base hypertrophy contributing to upper airway obstruction could be safely and effectively managed using TORS.5

TORS tongue base reduction has been described utilizing robotic instrumentation to perform a lingual tonsillectomy combined with midline glossectomy and supraglottoplasty.6 A number of studies have evaluated the outcomes of this technique. Friedman et al. studied patients undergoing z-palatoplasty and TORS base of tongue reduction and compared them to two other cohorts treated with tongue base procedures. One cohort underwent radiofrequency base of tongue reduction, and the other underwent coblation reduction of the tongue base. Each also underwent z-palatoplasty. They found the TORS cohort to have a significantly greater reduction in apnea hypopnea index (AHI) than the other cohorts and a surgical cure rate of 66.7%.7 Miller et al. performed a meta-analysis in which they included six studies. This included 353 patients, 296 of which underwent multilevel sleep surgery with a palate procedure and TORS tongue base reduction. They found a significant reduction in AHI from a mean of 44.3 to 17.8 and a 68.4% success rate.8

A novel addition to the surgical options that can be utilized to treat tongue base obstruction is upper airway stimulation (UAS) (Inspire Medical Systems, Minneapoliis MN). With this technology, the hypoglossal nerve is

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selectively stimulated to induce muscle tone in the upper airway, relieving obstruction and reducing the apnea and hypopnea burden. The device consists of three components: the stimulation lead, which is placed on the protrusor branches of the hypoglossal nerve; the respiratory sensor, which is placed between the internal and external intercostal muscles; and the internal pulse generator. With the device active, a gentle electrical stimulation is delivered to the hypoglossal nerve with each respiration. Although the main mechanism of this technology is to induce muscle contraction of the tongue and improve tongue base obstruction, there is evidence that it also improves obstruction at the velum through coupling of the palatoglossus muscle.9,10

With this article, we aim to compare a cohort of patients with OSA and tongue base obstruction undergoing treatment with TORS base of tongue resection to a group undergoing UAS. We hypothesize that patients undergoing UAS will have improved outcomes, a shorter hospital course, and lower complication rate compared to those undergoing TORS.

MATERIALS AND METHODS

After institutional review board approval at Thomas Jefferson University, Philadelphia, Pennsylvania, we designed a retrospective review of the senior author’s surgical database (MB). We included patients between January 2011 and July 2017 with a history of moderate to severe OSA who were intolerant to continuous positive airway pressure (CPAP) therapy, who were found to have a component of tongue base obstruction contributing to their OSA, who underwent either TORS tongue base resection or UAS, and who had a postoperative sleep study performed.

We documented demographic data including gender, body mass index (BMI), age, and prior sleep surgery. We also assessed pre- and postoperative PSG data, including AHI and O₂ desaturation nadir. We calculated the percent of patients reaching surgical success, a postoperative AHI less than 15, and a postoperative BMI less than 5. We defined surgical success as a postoperative AHI decreased by at least 50% from the preoperative value and to less than 20%. Lastly, we documented surgical complications, length of hospital stay, and number of patients requiring an unplanned readmission to the hospital after discharge. We defined major complications in the UAS cohort as hematoma, bleeding requiring return to the operating room, operative site infection, hypoglossal nerve paralysis, marginal mandibular nerve paralysis, and pneumothorax. We defined major complications in the TORS cohort as postoperative hemorrhage, airway obstruction, aspiration, hypoglossal nerve injury, and lingual nerve injury. Unplanned readmission was defined as readmission to the hospital within 30 days of discharge.

Since the clinical availability of UAS (Inspire Medical Systems, Minneapolis MN), it has largely replaced TORS in our practice for patients with OSA and an element of tongue base obstruction. Patients with moderate to severe OSA, who are unable to tolerate CPAP, and who have appropriate findings on drug-induced sleep endoscopy are candidates for UAS. We still perform TORS in patients who are found to have lingual tonsil hypertrophy contributing to their obstruction.

We compared the data points highlighted above in the cohort of patients undergoing UAS to those undergoing TORS. Statistical analysis was performed using SPSS version 24 (IBM Corp., Armonk, NY) for analysis. Fisher exact test was used to compare categorical data and a nonparametric Mann-Whitney U test was used to compare continuous data.

RESULTS

During the study period, 37 TORS and 94 UAS were performed at our institution. Twenty-four patients undergoing TORS and 76 patients UAS met inclusion criteria and were included in the analysis.

The TORS cohort consisted of 20 men and four women with a mean age of 46.42 and mean preoperative BMI of 29.63. Sixteen patients underwent prior surgery for OSA, which included 15 uvulopalatopharyngoplasty or expansion sphincteroplasty, one genioglossus advancement, two hyoid myotomy and advancement, and one mandibulomaxillary advancement. The mean preoperative AHI and O₂ desaturation nadir were 35.70 and 80.50, respectively. The UAS cohort consisted of 50 men and 26 women with a mean age of 61.92 and mean preoperative BMI of 29.38. Fourteen patients underwent prior surgery for OSA, which included 10 uvulopalatopharyngoplasty or expansion sphincteroplasty, one TORS base of tongue resection, one hyoid myotomy and advancement, and three mandibulomaxillary advancement. The mean preoperative AHI and O₂ desaturation nadir were 36.64 and 80.27, respectively. In comparing the cohorts, we found a significant difference in mean age ($P < 0.0001$) (Table II).

The mean postoperative AHI and O₂ desaturation nadir in the patients in the TORS cohort were 20.05 and 84.10, respectively. The rate of surgical success, patients reaching an AHI less than 15, and 5 were 54.17%, 50.00%, and 20.83%, respectively. The mean postoperative AHI and O₂ desaturation nadir in the patients in the UAS cohort were 7.20 and 88.77, respectively. The rate of surgical success, patients reaching an AHI less than 15, and 5 were 86.84, 89.47, and 59.21 respectively. All postoperative data points were significantly different between cohorts (Table II) (Fig. 1).

The patients in the TORS cohort had a mean length of hospital stay of 1.33 days. Four of the 24 patients had a 30-day unplanned readmission for dehydration and pain control. There were no major complications in this

![Table I. Demographic and Preoperative PSG Data](http://www.journals.com/doi/pdf/10.1002/lary.27198?recommended=1&request=relfulltext)
cohort, including no cases of postoperative hemorrhage. All patients in the UAS cohort underwent ambulatory surgery, and the mean length of hospital stay was zero days. Zero patients were readmitted to the hospital, and there were no major complications.

**DISCUSSION**

Obstructive sleep apnea (OSA) is a disease state characterized by recurrent upper airway obstruction during sleep limiting or completely impeding airflow. Obstruction can be unifocal or occur at multiple anatomic levels, including the velum, lateral pharynx, tongue base, and epiglottis. The primary treatment modality is positive airway pressure (PAP) therapy. However, for those unable to tolerate PAP therapy, a variety of techniques have been developed to alleviate obstruction. These include soft tissue procedures designed to remove redundant tissue or alter the anatomical construct of the palate or tongue base. Additionally, boney framework procedures designed to alter the facial skeleton have been used to alleviate airway obstruction.

The concept of stimulating the hypoglossal nerve to induce muscle contraction and alleviate upper airway obstruction was first developed in the 1980s. After numerous derivations, it was discovered that the branches of the hypoglossal nerve innervating the protrusor muscle of the tongue, the genioglossus, needed to be selectively stimulated to obtain maximum benefit. Schwartz et al. conducted a trial in which they selectively stimulated the protrusor branches and found a significant improvement in AHI and O\textsubscript{2} desaturation nadir. \textsuperscript{16}

In 2014, the initial clinical trial, the stimulation therapy for apnea reduction (STAR) trial, was published and showed significant improvement in AHI, O\textsubscript{2} desaturation nadir, Epworth sleepiness scores (ESS), and functional outcomes of sleep questionnaire (FOSQ) scores. \textsuperscript{17} Since the initial STAR publication, the cohort of patients has been reevaluated at 18, 24, 36, 48, and 60 months postoperatively. Objective PSG data and subjective quality of life have shown improvement and maintenance of benefit with therapy over the 5-year study period. The median AHI at 5-year follow-up was 6.2, decreased from a baseline of 29.3. Similarly, there was continuation of benefit with ESS and FOSQ scores. The median ESS was 6, within the normal range, at 5-year follow-up with use of therapy. \textsuperscript{18–22}

These findings have been confirmed by numerous single and multi-institutional outcomes articles. Kent et al. conducted a case series evaluating 20 patients. They found a decline in AHI from 33.3 to 5.1 and in ESS from 10.3 to 6 with therapy. \textsuperscript{23} Our group previously conducted a study in which 48 patients undergoing UAS at Thomas Jefferson University was combined with 49 patients from the University of Pittsburgh. In combining the cohorts, there was a significant improvement in AHI, O\textsubscript{2} desaturation nadir, and ESS postoperatively. Comparing the two cohorts, there was no difference in postoperative AHI or the rate of surgical success, suggesting reproducible results at high volume centers. \textsuperscript{24} Heiser et al. evaluated their cohort of patients with sleep studies at 2, 3, 6, and 12 months after implantation. They found a significant improvement in AHI, oxygen desaturation index, and ESS at the 12-month evaluation compared to baseline. The AHI at baseline, 2, 3, 6, and 12 months was 32.9, 11.5, 10.3, 7.6, and 7.1, respectively. \textsuperscript{25}

Prior to FDA approval of UAS, our departmental approach was to identify the location of upper airway obstruction through physical exam and flexible fiberoptic endoscopy. Those patients with contributing lingual tonsil hypertrophy or tongue base obstruction were offered TORS tongue base reduction. This was done as part of a multilevel approach in appropriate candidates. After the adoption of UAS, we started implementing this technique for patients with multilevel obstruction, including anteroposterior palate collapse and tongue base obstruction. \textsuperscript{26} We continue to utilize TORS tongue base reduction in those patients whose tongue base obstruction includes lingual tonsillar hypertrophy.

With this study, we found that those patients undergoing TORS were significantly younger when compared to those undergoing UAS. The UAS cohort had lower postoperative AHI, O\textsubscript{2} desaturation nadir, length of hospital stay, and postoperative improvement in AHI and O\textsubscript{2} desaturation nadir. Epworth sleepiness scores (ESS), and functional outcomes of sleep questionnaire (FOSQ) scores. \textsuperscript{27}

**TABLE II.**

<table>
<thead>
<tr>
<th>Postoperative PSG Data, Complication Rates, and Hospital Data of the TORS and UAS Cohorts</th>
<th>TORS</th>
<th>UAS</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postoperative AHI</td>
<td>20.05 ± 19.98</td>
<td>7.20 ± 11.12</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Postoperative (\text{O}_2) nadir</td>
<td>84.10 ± 8.87</td>
<td>88.77 ± 3.24</td>
<td>0.001</td>
</tr>
<tr>
<td>Success (%)</td>
<td>54.17</td>
<td>86.84</td>
<td>0.001</td>
</tr>
<tr>
<td>Postoperative AHI &lt; 15 (%)</td>
<td>50</td>
<td>89.47</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Postoperative AHI &lt; 5 (%)</td>
<td>20.83</td>
<td>59.21</td>
<td>0.001</td>
</tr>
<tr>
<td>Length of stay (days)</td>
<td>1.33</td>
<td>0</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Readmission rate (%)</td>
<td>16.67</td>
<td>0</td>
<td>0.003</td>
</tr>
<tr>
<td>Complications</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Data Listed as mean ± standard deviation. AHI = apnea-hypopnea index; PSG = polysomnography; TORS = transoral robotic surgery; UAS = upper airway stimulation.

*Fig. 1. Rate of surgical success, patients reaching an AHI less than 15, and five of each cohort. Success defined as a drop in postoperative AHI by 50% and to a value less than 20 compared to baseline. *Significant difference between cohorts. AHI = apnea-hypopnea index. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]*
CONCLUSION

We recognize the limitations of this study. It was designed in a retrospective manner and is of limited sample size. There is also an element of selection bias intrinsic to the study. We performed TORS prior to the adoption of UAS at our institution. TORS is best suited for those patients with base-of-tongue hypertrophy secondary to enlarged lingual tonsils and limited muscular obstruction. In those patients with muscular obstruction, the amount of tissue that can be resected is limited secondary to the development of postoperative speech and swallowing complications. Prior to the use of UAS, TORS was our primary tongue base procedure, and some patients with limited lingual tonsillar hypertrophy may have been better served with UAS. In addition, UAS could be considered a multilevel procedure because it targets tongue base obstruction but also improves airway caliber at the velum. This limits direct comparison to TORS base of tongue reduction. However, approximately two-thirds of our cohort underwent a prior palate procedure. This is reiterated by the previously published literature evaluating TORS in which the majority of the cohorts underwent a multilevel approach.

BIBLIOGRAPHY