World Journal of Otorhinolaryngology-Head and Neck Surgery (2017) 3, 101–105

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.keaipublishing.com/WJOHNS; www.wjent.org

Research Paper

# Transoral robotic surgery *vs.* endoscopic partial midline glossectomy for obstructive sleep apnea☆

**David Folk** [a,*], **Mark D'Agostino** [a,b]

[a] *Yale University, Section of Otolaryngology, Department of Surgery, New Haven, CT, USA*
[b] *Middlesex Hospital, Middletown, CT, USA*

Received 5 April 2017
Available online 23 June 2017

**KEYWORDS**
Sleep surgery;
Transoral robotic surgery;
TORS;
Midline glossectomy;
Partial glossectomy;
Posterior glossectomy

**Abstract** *Objective:* To compare sleep-related outcomes in obstructive sleep apnea hypopnea syndrome (OSAHS) patients following base of tongue resection via robotic surgery and endoscopic midline glossectomy.
*Methods:* This was a retrospective study. A total of 114 robotic and 37 endoscopic midline glossectomy surgeries were performed between July 2010 and April 2015 as part of single or multi-level surgery. Patients were excluded for indications other than sleep apnea or if complete sleep studies were not obtained. Thus, 45 robotic and 16 endoscopic surgeries were included in the analysis.
*Results:* In the robotic surgery group there were statistically significant improvements in AHI [(44.4 ± 22.6) events/h−(14.0 ± 3.0) events/h, $P < 0.001$] Epworth Sleepiness Scale (12.3 ± 4.6 to 4.5 ± 2.9, $P < 0.001$), and $O_2$ nadir (82.0% ± 6.1% to 85.0% ± 5.4%, $P < 0.001$). In the endoscopic group there were also improvements in AHI (48.7 ± 30.2 to 27.4 ± 31.9, $P = 0.06$), Epworth Sleepiness Scale (12.6 ± 5.5 to 8.3 ± 4.5, $P = 0.08$), and $O_2$ nadir (80.2% ± 8.6% to 82.7% ± 6.5%, $P = 0.4$). Surgical success rate was 75.6% and 56.3% in the robotic and endoscopic groups, respectively. Greater volume of tissue removed was predictive of surgical success in the robotic cases (10.3 *vs.* 8.6 ml, $P = 0.02$).

☆ This manuscript was presented at the AAO-HNSF annual meeting on September 29, 2015 as an oral presentation.
* Corresponding author. 800 Howard Avenue 4th Floor, Yale Physicians Building, New Haven, CT 06510, USA.
*E-mail address:* David.folk@yale.edu (D. Folk).
Peer review under responsibility of Chinese Medical Association.

Production and Hosting by Elsevier on behalf of KeAi

http://dx.doi.org/10.1016/j.wjorl.2017.05.004

*Conclusions:* Both robotic surgery and endoscopic techniques for tongue base reduction improve objective measures of sleep apnea. Greater success rates may be achieved with robotic surgery compared to traditional methods.


## Introduction

Obstructive sleep apnea/hypopnea syndrome (OSAHS) is a disorder with numerous well-described adverse health consequences. It is a known risk factor for cardiovascular disease, insulin resistance, stroke, and death.[1,2] Continuous positive airway pressure (CPAP) is the gold standard treatment for OSAHS, as it has been shown to be highly effective in reducing daytime somnolence, improving sleep, and ameliorating adverse health outcomes.[3] The effectiveness of CPAP is directly related to its proper use, however, nonadherence rates as high as 46%–83% have been described.[4]

Surgical treatment of OSAHS has played an increasingly important role, especially in those unable to adhere to CPAP. Fujita et al[5] described the technique of uvulopalatopharyngoplasty (UPPP) in 1981, which was designed to enlarge the oropharyngeal aperture and improve obstruction. Such procedures targeting the soft palate and oropharynx are frequently performed today, however, their effectiveness has been debated. One meta-analysis of surgical modifications of the upper airway describes the paucity of high-level evidence and ambiguity in defining surgical success in the literature.[6] In this same report, UPPP was found to reduce AHI overall by 33% although residual AHI remained elevated at 29.8 on average. Fortunately, recent technological advances demonstrate great promise in the surgical management of OSAHS.

The importance of the tongue base in OSAHS has long been recognized.[7] Gaining adequate access to this region, however, can be challenging especially given the critical neurovascular structures that exist. Residual obstructions at the tongue base are found in up to 17%–33% of patients.[8] Thus a variety of procedures have been described to target this region with the goal of improving surgical success rates. Fujita et al[9] was the first to describe the removal of tongue base tissue, which was performed using the $CO_2$ laser and microscopic visualization. Technological advances gave way to the use of endoscopes coupled with various other minimally invasive methods for tongue base removal. Most recently, transoral robotic surgery (TORS) was approved for benign and malignant lesions of the tongue base, and its applications have increased steadily since then. Initially pioneered by Weinstein and O'Malley for oncologic purposes, frequently cited advantages of TORS include improved visualization and access.[10–12] Robotic surgery has been shown to be safe and feasible in benign diseases including OSAHS.[13] Prior reports describe TORS for tongue base resection alone, as well as in conjunction with other upper airway procedures.[14–16] In this study, we describe our results with a relatively large series of patients who underwent endoscopic partial midline glossectomy (PMG) as well as TORS for OSAHS. To the best of our knowledge, this is the first study to conduct such a comparison.

## Methods

The present study is a retrospective review of single-institution series of TORS and PMG cases for OSA. Between July 2010 and April 2015 a total of 114 patients underwent TORS and 37 underwent PMG for BOT resection. Patients were excluded from the analysis if their data was incomplete, including pre- and post-operative polysomnography, or if TORS was performed for an indication other than OSAHS. Given these criteria, 45 TORS and 16 PMG patients were included in the analysis. A single surgeon (MD) performed all of the cases. Demographic and clinical data for each patient included age, gender, BMI, sleep endoscopy, Epworth sleepiness scale (ESS), apnea–hypopnea index (AHI), Friedman stage, tonsil size, volume of tissue resected, $O_2$ nadir, and concomitant surgeries performed. The study was approved by the IRB of Middlesex Hospital, CT.

### Statistical analysis

Statistical analyses were performed using Excel 14.3.2 (Microsoft Corporation). Two tailed student *t*-test was used to compare groups with a $P < 0.05$ deemed statistically significant.

### Patient selection

All patients had a diagnosis of OSAHS made by polysomnography and had failed at least one and, in many cases, several trials of CPAP. Some patients had also failed treatment with an oral appliance and/or previous surgery. All patients were examined by the senior author for nasal, oropharyngeal and hypopharyngeal obstruction. BMI, ESS, Friedman staging and flexible fiberoptic nasopharyngoscopy (including Muller maneuver) findings were recorded. In most patients the level of obstruction was confirmed by sleep endoscopy performed at the start of the procedure.

### Surgical technique

The surgical technique used was similar to that previously described by Vicini et al.[14] All patients underwent oral intubation, and there were no tracheostomies or feeding tubes used in any patient. Sleep endoscopy and any concurrent nasal or oropharyngeal procedure were performed at the same time as the BOT resection. Exposure of the base of tongue was obtained in most cases using a Crowe-Davis mouth gag with various size Davis-Myer tongue blades. For PMG cases, the Doppler probe was used to map out the lingual arteries. Thirty and seventy-degree Hopkins rods were used for visualization. Lingual tonsillar tissue and tongue muscle was then removed using the coblator device. For TORS cases, the DaVinci robotic system (Intuitive Surgical, Sunnyvale CA) with 5 mm EndoWrist instruments (a Spatula Tip for monopolar cauterization and Maryland Dissector) and 8 mm 3D endoscopes were used. Dissection was performed from the circumvallate papillae down to the base of the epiglottis and valleculae on each side. No epiglottidectomies were performed. Muscle was then resected from each side in a similar fashion (up to 10 mm) and if needed additional muscle (up to another 5 mm) was removed in the midline. The amount of tissue removed was recorded in ml by measuring volume displaced in a syringe. This volume varied based on each patient's anatomy. Hemostasis was obtained during the dissection using the monopolar cautery. All but one patient were extubated in the operating room. One patient who had COPD was left intubated over night and extubated on postoperative day #1. All patients were observed overnight in a monitored bed and all were discharged home on postoperative day #1.

## Results

Patient demographics and characteristics: There were 33 males (73%) and 12 females (27%) with a mean age of 48.2 ± 11.6 in the TORS group. There were 12 males (75%) and 4 females (25%) with a mean age of 46.3 ± 8.4 in the PMG group. The overall mean preoperative BMI was 32.3 ± 4.5 kg/m$^2$. Overall, twenty-three patients underwent prior upper airway procedures that included tonsillectomy, UPPP, pillar implants, turbinate reduction, and septoplasty. The mean Friedman stage was 2.6 ± 0.5. The mean overall ESS preoperatively was 12.4 ± 4.8 and the mean AHI preoperatively was 45.5 ± 24.6 (Table 1).

Surgical characteristics: The mean volume of tissue removed in the TORS group was 9.9 ± 2.1 ml. No tracheotomies were performed as part of the surgery. Of the 45 patients who underwent TORS, 6 patients received BOT resection alone and 31 underwent BOT resection in conjunction with other concurrent procedures. In the PMG group of 16 patients, 3 underwent single site surgery at the BOT alone. The additional upper airway surgeries included turbinate reduction, tonsillectomy, septoplasty, and UPPP. All patients were monitored overnight in a surgical step-down unit and discharged home the following day.

Outcomes following TORS BOT surgery: There were statistically significant reductions in AHI, ESS and $O_2$ nadir. The AHI decreased from (44.4 ± 22.6) events/h to (14.0 ± 3.0) events/h, with an average AHI reduction of 68% ($P < 0.001$). There were reductions in daytime somnolence measured by the ESS from 12.3 ± 4.6 to 4.5 ± 2.9 ($P < 0.001$). The $O_2$ nadir was 82.0% ± 6.1% preoperatively and 85.0% ± 5.4% postoperatively ($P < 0.001$). Surgical success was defined as a final AHI < 20 events/h and an AHI reduction ≥50%. By this definition, there was a surgical success rate of 75.6% (34/45) (Table 2).

Outcomes following PMG surgery: The AHI decreased from (48.7 ± 30.2) events/h to (27.4 ± 31.9) events/h, with an average AHI reduction of 44% ($P = 0.06$). There were reductions in ESS from 12.6 ± 5.5 to 8.3 ± 4.5 ($P = 0.08$). The $O_2$ nadir was 80.2% ± 8.6% preoperatively and 82.7% ± 6.5% postoperatively ($P = 0.4$). There was a surgical success rate of 56.3% (9/16) (Tables 2 and 3).

Comparison between single-level and multilevel surgical patients: The results were stratified based on whether patients underwent surgery at the level of the BOT only *vs.* multilevel upper airway surgery including BOT resection. Paired *t* tests were performed to analyze this data. There was no statistically significant difference in surgical response ($P = 0.15$).

Comparison between surgical responders and non-responders: The results were analyzed with respect to various patient characteristics to determine if any factors were predictive of surgical success. There was noted to be a significant correlation between volume of tissue removed and surgical success rates in the TORS group, with more tissue removed on average in those patients who responded to surgery (10.3 ml *vs.* 8.6 ml, $P = 0.02$) (Tables 4 and 5).

**Table 1** Patient demographics and baseline characteristics.

| Characteristic | TORS group | PMG group |
|---|---|---|
| Males [cases, (%)] | 33 (73) | 12 (75) |
| Females (cases, (%)) | 12 (27) | 4 (25) |
| BMI(kg/m$^2$) | 32.3 ± 4.8 | 32.5 ± 3.5 |
| Volume tissue (ml) | 9.9 ± 2.1 | NA |
| Preoperative AHI (events/h) | 44.4 ± 22.6 | 48.7 ± 30.2 |
| Preoperative ESS | 12.3 ± 4.6 | 12.6 ± 5.5 |
| Preoperative $O_2$ nadir (%) | 82.0 ± 6.1 | 80.2 ± 8.6 |

TORS: transoral robotic surgery; PMG: partial midline glossectomy; AHI: apnea—hypopnea index; ESS: epworth sleepiness scale; NA: not available.

**Table 2** Preoperative *vs.* postoperative results (TORS group).

| Group | Apnea—hypopnea index (events/h) | Epworth sleepiness scale | $O_2$ nadir (%) |
|---|---|---|---|
| Preoperative | 44.4 ± 22.6 | 12.3 ± 4.6 | 82.0 ± 6.1 |
| Postoperative | 14.0 ± 13.0 | 4.5 ± 2.9 | 85.0 ± 5.4 |
| *P* value | <0.001 | <0.001 | <0.001 |

**Table 3** Preoperative *vs.* postoperative results (PMG group).

| Group | Apnea—hypopnea index (events/h) | Epworth sleepiness scale | $O_2$ nadir (%) |
|---|---|---|---|
| Preoperative | 48.7 ± 30.2 | 12.6 ± 5.5 | 80.2 ± 8.6 |
| Postoperative | 27.4 ± 31.9 | 8.3 ± 4.5 | 85.0 ± 5.4 |
| *P* value | 0.06 | 0.08 | 0.4 |

**Table 4** Comparison of surgical responders and nonresponders (TORS group).

| Group | Age (years) | BMI (kg/m$^2$) | Volume tissue removed (ml) | Friedman | Tonsil size |
|---|---|---|---|---|---|
| Responders | 47.3 | 32.0 | 10.3 | 2.7 | 1.7 |
| Nonresponders | 50.8 | 33.0 | 8.6 | 2.5 | 1.4 |
| *P* value | 0.4 | 0.6 | **0.02** | 0.4 | 0.6 |

Statistically significant value is represented in bold.

**Table 5** Comparison of surgical responders and nonresponders (PMG group).

| Group | Age (years) | BMI (kg/m$^2$) | Friedman | Tonsil size |
|---|---|---|---|---|
| Responders | 46.0 | 33.3 | 2.8 | 1.6 |
| Nonresponders | 46.6 | 31.4 | 2.3 | 1.5 |
| *P* value | 0.9 | 0.3 | 0.2 | 0.9 |

Complications: No intraoperative complications encountered. Nine patients experienced postoperative complications. Four patients experienced bleeding that was self-limited in the postoperative period. All bleeding resolved spontaneously by the time the patient was seen by an MD and no further treatment was required. One patient required inpatient treatment for pneumonia and dehydration postoperatively, however the pneumonia was judged not to be due to aspiration. Three other patients experienced postoperative dehydration requiring IV fluids administered in the emergency room. One patient complained of an increased gag sensation for several months postoperatively.

## Discussion

In this series, we compare the clinical and polysomnographic data of 45 patients who underwent TORS and 16 patients who underwent endoscopic PMG for OSAHS. Although still a relatively novel surgical technique, robotic surgery for the management of OSAHS has shown great potential as a treatment option for the properly selected patient. Considering the known importance of obstruction at the level of the BOT, it is not surprising that the robot offers advantages with its improved access and visualization. Vicini et al[16] first reported preliminary results on 10 patients treated with TORS for OSAHS. His described technique differs from ours in that he performed a tracheotomy in all patients. In a follow up study in 20 patients he reported statistically significant mean AHI reductions from (36.3 $\pm$ 21.1) events/h to (16.4 $\pm$ 15.2) events/h.[17] Friedman et al[14] showed that TORS for OSAHS could be safely performed without the need for a tracheotomy, which is the approach used in all of our cases. His report on 27 patients showed AHI improvements from (54.6 $\pm$ 21.8) events/h to (18.6 $\pm$ 9.1) events/h.[14] These prior series all described patients who underwent TORS in conjunction with other upper airway procedures for OSAHS. Lin et al[15] reported a 50% response rate with statistically significant reductions in AHI and ESS in 12 patients who underwent resection at the level of the BOT alone.

This study adds to the existing literature by reiterating the safety and effectiveness of TORS while also directly comparing it to more traditional methods performed by the same surgeon. Our results are comparable to those reported in other series. It is essential to appropriately select candidates for TORS, which includes targeting all of the hypertrophied or obstructing tissue for removal. Interestingly, in our study the only statistically significant difference noted that was predictive of surgical success was the volume of tissue removed, with a greater volume removed on average in those who responded to surgery. In the PMG group, volume of tissue was not recorded due to the fact that this technique ablates the tissue during removal.

In a recent study, Vicini et al report their results of single stage, multisite robotic-assisted surgery.[18] This consisted of tongue base reduction, supraglottoplasty, nasal surgery if required, and a palate procedure. While they show that expansion sphincter pharyngoplasty was superior to UPPP, their results highlight that TORS is perhaps most effective when used as part of multilevel surgery, addressing obstruction at each level in which it is encountered. Our results showed similar success rates in single level and multilevel patients. However, when targeting the BOT alone, there was a trend toward higher success rates in the TORS group (83% *vs*. 66%). These results are limited by the retrospective nature of this study, and further clinical studies are necessary despite these encouraging results.

## Conclusion

Our study provides further evidence that BOT resection as part of single or multilevel surgery can effect significant improvements in objective measures of OSA. Greater success rates may be achieved with TORS compared to traditional methods, and volume of tissue removed may be predictive of surgical success.

## Conflicts of interest

None.

## Financial disclosure

None.

## References

1. Shamsuzzaman AS, Gersh BJ, Somers VK. Obstructive sleep apnea: implications for cardiac and vascular disease. *JAMA*. 2003;290:1906–1914.

2. Punjabi NM, Caffo BS, Goodwin JL, et al. Sleep-disordered breathing and mortality: a prospective cohort study. *PLoS Med*. 2009;6:e1000132.
3. Marin JM, Carrizo SJ, Vicente E, Agusti AG. Long-term cardiovascular outcomes in men with obstructive sleep apnoea—hypopnoea with or without treatment with continuous positive airway pressure: an observational study. *Lancet*. 2005; 365:1046—1053.
4. Weaver TE, Grunstein RR. Adherence to continuous positive airway pressure therapy: the challenge to effective treatment. *Proc Am Thorac Soc*. 2008;5:173—178.
5. Fujita S, Conway W, Zorick F, Roth T. Surgical correction of anatomic abnormalities in obstructive sleep apnea syndrome: uvulopalatopharyngoplasty. *Otolaryngol Head Neck Surg*. 1981; 89:923—934.
6. Caples SM, Rowley JA, Prinsell JR, et al. Surgical modifications of the upper airway for obstructive sleep apnea in adults: a systematic review and meta-analysis. *Sleep*. 2010;33: 1396—1407.
7. Remmers JE, deGroot WJ, Sauerland EK, Anch AM. Pathogenesis of upper airway occlusion during sleep. *J Appl Physiol Respir Environ Exerc Physiol*. 1978;44:931—938.
8. Murphey AW, Kandl JA, Nguyen SA, Weber AC, Gillespie MB. The effect of glossectomy for obstructive sleep apnea: a systematic review and meta-analysis. *Otolaryngol Head Neck Surg*. 2015;153:334—342.
9. Fujita S, Woodson BT, Clark JL, Wittig R. Laser midline glossectomy as a treatment for obstructive sleep apnea. *Laryngoscope*. 1991;101:805—809.
10. O'Malley BW, Weinstein GS, Snyder W, Hockstein NG. Transoral robotic surgery (TORS) for base of tongue neoplasms. *Laryngoscope*. 2006;116:1465—1472.
11. Weinstein GS, O'Malley BW, Cohen MA, Quon H. Transoral robotic surgery for advanced oropharyngeal carcinoma. *Arch Otolaryngol Head Neck Surg*. 2010;136:1079—1085.
12. Weinstein GS, O'Malley BW, Snyder W, Sherman E, Quon H. Transoral robotic surgery: radical tonsillectomy. *Arch Otolaryngol Head Neck Surg*. 2007;133:1220—1226.
13. Hoff PT, D'Agostino MA, Thaler ER. Transoral robotic surgery in benign diseases including obstructive sleep apnea: safety and feasibility. *Laryngoscope*. 2015;125:1249—1253.
14. Friedman M, Hamilton C, Samuelson CG, et al. Transoral robotic glossectomy for the treatment of obstructive sleep apnea—hypopnea syndrome. *Otolaryngol Head Neck Surg*. 2012;146:854—862.
15. Lin HS, Rowley JA, Badr MS, et al. Transoral robotic surgery for treatment of obstructive sleep apnea—hypopnea syndrome. *Laryngoscope*. 2013;123:1811—1816.
16. Vicini C, Dallan I, Canzi P, Frassineti S, La Pietra MG, Montevecchi F. Transoral robotic tongue base resection in obstructive sleep apnoea—hypopnoea syndrome: a preliminary report. *ORL J Otorhinolaryngol Relat Spec*. 2010;72:22—27.
17. Vicini C, Dallan I, Canzi P, et al. Transoral robotic surgery of the tongue base in obstructive sleep apnea—hypopnea syndrome: anatomic considerations and clinical experience. *Head Neck*. 2012;34:15—22.
18. Vicini C, Montevecchi F, Pang K, et al. Combined transoral robotic tongue base surgery and palate surgery in obstructive sleep apnea—hypopnea syndrome: expansion sphincter pharyngoplasty versus uvulopalatopharyngoplasty. *Head Neck*. 2014;36:77—83.


Edited by Yu-xin Fang