The Effect of Glossectomy for Obstructive Sleep Apnea: A Systematic Review and Meta-analysis

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Abstract

Objective. Determine the effect of glossectomy as part of multilevel sleep surgery on sleep-related outcomes in patients with obstructive sleep apnea.

Data Sources. PubMed, Scopus.

Review Methods. Two independent researchers conducted the review using PubMed-NCBI and Scopus literature databases. Studies on glossectomy for obstructive sleep apnea that reported pre- and postoperative apnea-hypopnea index (AHI) score with 10 or more patients were included.

Results. A total of 18 articles with 522 patients treated with 3 glossectomy techniques (midline glossectomy, lingualplasty, and submucosal minimally invasive lingual excision) met inclusion criteria. Pooled analyses (baseline vs post surgery) showed a significant improvement in AHI (48.1 ± 22.01 to 19.05 ± 15.46, P < .0001), Epworth Sleepiness Scale (ESS; 11.41 ± 4.38 to 5.66 ± 3.29, P < .0001), snoring visual analog scale (VAS; 9.08 ± 1.21 to 3.14 ± 2.41, P < .0001), and Lowest O2 saturation (76.67 ± 10.58 to 84.09 ± 7.90, P < .0001). Surgical success rate was 59.6% (95% CI, 53.0%-65.9%) and surgical cure was achieved in 22.5% (95% CI, 11.26%-36.26%) of cases. Acute complications occurred in 16.4% (79/481) of reported patients. Glossectomy was used as a standalone therapy in 24 patients. In this limited cohort, significant reductions in AHI (41.84 ± 32.05 to 25.02 ± 20.43, P = .0354) and ESS (12.35 ± 5.05 to 6.99 ± 3.84, P < .0001) were likewise observed.

Conclusion. Glossectomy significantly improves sleep outcomes as part of multilevel surgery in adult patients with OSA. Currently, there is insufficient evidence to analyze the role of glossectomy as a standalone procedure for the treatment of sleep apnea, although the evidence suggests positive outcomes in select patients.

Keywords
glossectomy, midline glossectomy, lingualplasty, submucosal minimally invasive lingual excision, SMILE, obstructive sleep apnea, OSA, sleep surgery

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Introduction

Obstructive sleep apnea (OSA) is a common and morbid disease affecting approximately 9% of women and 24% of men aged 30 to 60 years.1,2 The disorder is characterized by narrowing and collapse of the pharyngeal airway during sleep that leads to reductions (hypopnea) and cessations (apneas) of airflow. The gold standard for the treatment of moderate to severe disease continues to be continuous positive airway pressure (CPAP); however, long-term compliance rates are poor despite the health benefits of CPAP therapy. Adherence is defined as ≥4 hours use/night. Of patients, 46% to 83% are labeled as nonadherent, and compliance rates significantly decrease after 1 year of therapy.3,4 While generally not as effective as CPAP, upper airway surgery is an option as salvage therapy in CPAP failures, reducing the physiological burden of the disorder while improving symptoms.

Uvulopalatopharyngoplasty (UPPP) was widely popularized by Fujita as treatment for OSA in 1980 and continues to be the mainstay of surgical therapy.5,6 However, studies have shown modest results with an overall rate of success of 40% in unselected patients.7 The failures of UPPP lie in the pathophysiology of OSA. Obstructions can occur at many areas along the upper airway, and 58% to 87% of patients with OSA have multilevel collapse.8-10 Residual obstructions along the tongue base account for 17% to 33% of upper airway collapse and is especially prominent in the obese and severe OSA (apnea-hypopnea index [AHI] >30)
populations. Therefore, adjunct therapies were developed with a focus on the tongue base and hypopharynx. Specific treatments, such as partial glossectomy, hyoid suspension, genioglossus advancement, and radiofrequency, have been utilized alone or as part of multilevel surgery with palate procedures in order to improve the rate of surgical success.

Although various techniques of partial glossectomy for OSA have been described, for the purposes of this review, partial glossectomy includes any procedure that removes tongue tissue in an effort to treat OSA. Sleep surgeries that fit this criterion include midline glossectomy (MLG), submucosal minimally invasive lingual excision (SMILE), and lingualplasty (LP). Fujita was the first to describe removal of tongue tissue for OSA with the MLG. MLG utilized as a salvage procedure in patients who failed to respond to UPPP was very successful and resulted in a mean reduction of respiratory disturbance index (RDI) of 19. Woodson and others have developed further modifications of MLG, such as LP, in an effort to improve outcomes results. LP extends tissue removal from MLG posteriorly and laterally. The resulting defect is sutured posterior to anterior, which advances and modifies the dorsal profile of the tongue base.

Due to morbidity of the initial techniques and concerns for the safety and preservation of the lingual artery and hypoglossal nerve, glossectomy has changed extensively over the years. Recent focus has been on minimally invasive techniques, such as SMILE, in which a coblator is inserted into the tongue through a midline incision and tissue is removed submucosally. However, MLG is gaining popularity again using transoral robotic surgery (TORS), which improves visualization of the surgical field, thereby maximizing tissue removal while minimizing risk to vital structures. The goal of this review is to determine the sleep-related outcomes of partial glossectomy as part of multilevel surgery and when possible its role as a single, standalone surgery for OSA.

Materials and Methods

Literature Search

Two independent comprehensive literature searches using PubMed-NCBI and SCOPUS databases were performed using the following previously defined terms: (1) glossectomy AND “sleep apnea,” (2) “midline glossectomy” AND “sleep apnea,” (3) lingualplasty AND “sleep apnea,” (4) “lingual excision” AND “sleep apnea,” and (5) “tongue base” AND “sleep apnea.” Results were limited to the English language. Articles were screened according to their titles, and abstracts were chosen for review to determine eligibility for inclusion based on predetermined criteria. The reference lists of all identified articles were examined for additional studies. The literature search strategy and results can be found in the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) compliant literature review diagram (Figure 1). Study design was a retrospective literature review; therefore, Institutional Review Board approval was not necessary for this study.

Inclusion Criteria

1. Treated patients carried a previous diagnosis of OSA or diagnosis was confirmed with a preoperative polysomnogram (PSG) demonstrating an AHI (RDI) >5;
2. Pre- and posttreatment data for at least 1 of the established endpoint measures, including AHI, Epworth Sleepiness Scale (ESS), Lowest O2 saturation (LSAT), and/or snoring visual analog scale (VAS);
3. Treatment clearly describes the removal of tongue tissue alone or as part of a multilevel surgery;
4. Study included 10 or more total patients;
5. Adult patients >18 years of age.

Exclusion Criteria

1. Manuscripts not available in English;
2. Any studies that examined tongue reduction without evidence of actual tongue tissue removal, namely, radiofrequency procedures;
3. Any procedures that involved open, cervical approaches to the tongue base or hypopharynx.

Data Extraction

Data from studies meeting inclusion criteria were extracted using a standardized form and verified by a second author (J.K). The form was generated prior to article review. The primary outcomes of interest included postoperative changes in AHI, ESS, and LSAT; surgical success; and surgical cure rate. Surgical success was defined as a reduction in AHI by >50% and a final AHI <20, and surgical cure was defined as postoperative AHI <5. Other study data collected included sample size, patient demographics, length to follow-up, and associated procedures. Prior to 2005, RDI was commonly used interchangeably with AHI. For those articles, methods sections were carefully read to confirm RDI was the same as traditional AHI measurements. Once confirmed, RDI was counted as AHI. The articles after 2005 specifically and consistently use AHI. When both AHI and RDI were listed as outcome measures, only the AHI was used. In some cases, the means and standard deviations (SD) were computed using either postoperative percentage change or per patient statistics. No computational discrepancies between the 2 independent authors occurred. If articles did not contain the correct endpoints or were missing data, 2 attempts were made to contact the corresponding author. If no response was received, the article was excluded. In 1 article, the SD was unavailable for the postoperative changes in AHI. After attempts for contact were unsuccessful, a weighted average was performed using the data from the other manuscripts, and this value was used for analysis.

Stat Section

The meta-analysis utilized a pretreatment (baseline) to postglossectomy comparison, with all subjects serving as their
own controls. Each treatment outcome was assessed and recorded as an absolute value and/or change from baseline using the last time-point data available. Data reported in graphical plots were not extracted for pooled meta-analysis unless numerical points were discernible or the authors of the relevant trial supplied additional data.

Meta-analysis of selected studies with a continuous measure (comparison of means and standard deviations between baseline and post-glossectomy groups) was performed with Cochrane Review Manager (RevMan) version 5.3 (The Nordic Cochrane Centre, The Cochrane Collaboration, 2011, Copenhagen, Denmark). Both the fixed effects model and the random effects model were used in this study. Under the fixed effects model, it is assumed that the studies share a common true effect, and the summary effect is an estimate of the common effect size. Under the random effects model, the true effects in the studies are assumed to vary between studies, and the summary effect is the weighted average of the effects reported in the different studies. The random effects model provides a more conservative estimate (ie, with a wider confidence interval [CI]), but the results from the 2 models usually agree when there is no heterogeneity. When heterogeneity was present, the random effects model was the preferred model. This assumption was tested by the heterogeneity test or I² statistic. If the heterogeneity test yielded a low P value (P < .05), the fixed effects model was invalid. In this case, the random effects model was more appropriate, in which both the random variation within the studies and the variation between the different studies was incorporated.

For this study, the null hypothesis was that there was no difference between baseline and post-glossectomy with respect to AHI, ESS, and LSAT. Effect sizes were calculated using mean differences (MDs) with corresponding 95% CIs. If the value of 0 is not within the 95% CI range, then the MD was statistically significant at the 5% level (P < .05).

In addition, a meta-analysis of proportion was done for surgical success rate. The program MedCalc 14.12.0 (MedCalc Software bvba, Belgium) lists the proportions...
(expressed as a percentage), with their 95% CI, found in the individual studies included in the meta-analysis. The pooled proportion with 95% CI is given both for the fixed effects model and the random effects model. Each technique was weighted according to the number of patients treated. Analysis of pooled proportions was performed where appropriate. MedCalc used a Freeman-Tukey transformation to calculate the weighted summary proportion under the fixed and random effects model.\(^\text{18,19}\) Data were presented as weighted proportions with corresponding 95% CIs. Both the fixed effects model and the random effects model were used in this study.

### Results

The literature search resulted in a total of 1240 manuscripts, of which only 18 met the inclusion and exclusion criteria (Table 1). Robinson et al\(^\text{21}\) discusses a technique where a coblator was inserted percutaneously through a suprahyoid incision to resect tongue tissue. This was not considered a true cervical approach and was therefore included in analysis. It was later modified to the current SMILE technique and thus considered as such. Two studies investigated more than 1 glossectomy technique. Friedman et al\(^\text{25}\) analyzes MLG using a SMILE control group, and Babademez et al\(^\text{23}\) compares results of 3 minimally invasive tongue base procedures (MLG, SMILE with coblator, and SMILE with harmonic scalpel). For both manuscripts, each technique was analyzed as a separate study and labeled in figures (Friedman 2012A, B and Babademez 2011A, B, C, respectively).

The majority of manuscripts include glossectomy as part of a multilevel surgical approach; however, 3 manuscripts, with a total of 24 patients, analyze glossectomy alone without concurrent surgical procedures. H.S. Lin et al\(^\text{20}\) presents 12 patients undergoing glossectomy via TORS as an isolated surgery. The other 12 patients were obtained from 2 other manuscripts that study both multilevel surgery and isolated glossectomy.\(^\text{21,22}\) All 3 studies include pre- and postoperative values for AHI, ESS, and LSAT. Separate analysis was conducted using these 24 patients only. Therefore, their data were not included in the meta-analysis for the multilevel surgery group.

### Demographics

A total of 522 patients underwent glossectomy procedures, 498 multilevel surgery and 24 isolated tongue base surgery. Patients were predominantly male (84.4%) with a mean age of 45.75 years. Mean pre-procedure BMI was 29.4 (mean range, 26.5-36). The median time to follow-up with PSG was 6 months (range, 6 weeks-21 months). Inclusion and exclusion criteria varied among studies, but a common theme was applicable across cohorts. All included subjects had evidence of moderate to severe OSA (AHI >15), CPAP intolerance or failure, and evidence of hypopharyngeal collapse. Hypopharyngeal obstruction was predicted by physical exam, nasal endoscopy, clinical staging, Friedman type 3/4 or Fujita type 2b/3, or with imaging (cephalometry or computed tomography [CT]).
Apnea-Hypopnea Index
Seventeen studies, with 498 subjects, record pre- and postoperative PSG confirmed AHI for multilevel surgery. Comparison of means reveals a statistically significant mean reduction in AHI of 48.1 ± 22.01 to 19.05 ± 15.46 (P < .001) from baseline to follow-up. Pooled analysis also shows a significant improvement in AHI, -22.61 (95% CI, -33.00 to -12.22) (Figure 2).

Epworth Sleepiness Scale
Ten studies, totaling 331 patients, record pre- and postoperative ESS scores. Comparison of means reveals a statistically significant improvement in ESS, 11.41 ± 4.38 to 5.66 ± 3.29 (P < .001) from baseline to follow-up. Pooled analysis also shows a significant improvement in ESS, -5.49 (95% CI, -7.17 to -3.81) (Figure 3).

LSAT
Fifteen studies, totaling 414 patients, recorded pre- and postoperative LSAT. Comparison of means reveals statistically significant improvement in LSAT, 76.67% ± 10.58% to 84.09% ± 7.90% (P < .001), from baseline to follow-up. Pooled analysis also shows a statistically significant improvement in LSAT, 7.68 (95% CI, 5.34-10.02) (Figure 4).

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**Figure 2.** Forest plot depicting mean apnea hypopnea index change after glossectomy.

**Figure 3.** Forest plot depicting mean Epworth Sleepiness Scale change after glossectomy.

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Snoring VAS
Five studies, totaling 197 patients, recorded pre- and postoperative snoring VAS scales. Comparison of means reveals a statistically significant decrease in VAS, 9.08 ± 1.21 to 3.14 ± 2.41 (P < .001), from baseline to follow-up. Pooled analysis also shows significant improvement in snoring VAS −5.60 (95% CI, −6.57 to −4.63) (Figure 5).

Surgical Success
Fifteen studies, totaling 414 patients, were analyzed for surgical success. Surgical success was considered to be a postoperative AHI <20 and reduction from preoperative AHI >50%. Pooled analysis reveals success was achieved in 59.56% (95% CI, 52.99%-65.96%) of cases (Figure 6).

Surgical Cure
Seven studies, totaling 175 patients, were analyzed for surgical cure. Surgical cure was defined as postoperative AHI <5. Pooled analysis reveals cure was achieved in 22.5% (95% CI, 11.26%-36.26%) of cases.

Glossectomy Only
Three studies, totaling 24 patients, analyzed glossectomy alone without concurrent surgical procedures. Comparison of means reveals a statistically significant reduction in both AHI (41.84 ± 32.05 to 25.02 ± 20.43, P = .04) and ESS (12.35 ± 5.05 to 6.99 ± 3.84, P = .001) from baseline to follow-up. Pooled analysis also reveals significant reduction in ESS, −5.41 (95% CI, −7.76 to −3.05), from baseline to follow-up. Pooled analysis is not significant for AHI or LSAT. Data were not available for snoring VAS or surgical success.

Complications
Complications were published in 16 of 18 analyzed manuscripts. They were broken down into acute (<30 days post procedure) and chronic (>30 days). Acute complications...
Results were impressive, showing reduction in AHI (36.4). Map out the lingual artery before open midline glossectomy. Who utilized Computed Tomography Angiography (CTA) to best results across all outcomes were seen with Li and Shi,29 plan significantly improved outcomes across 4 independent levels of treatment. Their first 10 patients received plasma suspension, and/or geniotubercle advancement), which is slightly less than the success rate found in our study (59.6%). Our success rate is also similar to other multilevel surgeries including genioglossus advancement and hyoid suspension, which at one time was considered first-line therapy for hypopharyngeal obstruction.

Discussion

Glossectomy has almost exclusively been studied as part of multilevel surgery, and unlike other tongue therapy such as radiofrequency, few direct comparisons to other procedures have been made. This study is one of the first to gather data on the role of glossectomy alone and as part of multilevel surgery on such a large scale. Our analysis showed that glossectomy, as part of multilevel surgery, significantly improves sleep outcomes in adult patients with obstructive sleep apnea.

When combined with palate surgery as multilevel surgical treatment, glossectomy appears to be effective. Data indicate that including glossectomy as part of a multilevel surgical plan significantly improved outcomes across 4 independent sleep metrics, including AHI, ESS, LSAT, and VAS. The best results across all outcomes were seen with Li and Shi,29 who utilized Computed Tomography Angiography (CTA) to map out the lingual artery before open midline glossectomy. Results were impressive, showing reduction in AHI (36.4) and ESS (9.3) and an increase in LSAT of 17%. Such impressive results were most likely due to strict inclusion criteria, including preoperative CT-confirmed hypopharyngeal airway space <180 mm. This further demonstrates that in such a site-specific sleep surgery, such as UPPP and glossectomy, determination of site obstruction is imperative.

Combined surgical success rate for all studies was 59.6% while surgical cure was achieved in 22.5% of cases. Despite its popularity, the definition used for success, >50% improvement and AHI <20, is far from ideal. It excludes drastic improvements in AHI or improvements in other sleep outcomes. For example, Mickelson and Rosenthal only reported a success rate of 25% (3/12). However, mean AHI was reduced by 26.7, which is similar to the mean reduction across all 18 of our reported studies. The LSAT also improved by 19% in the 9 nonresponders.

Although other reviews have analyzed glossectomy in the past, many have not fully analyzed outcome parameters that have clinical significance. One review analyzed glossectomy as part of multilevel surgery and compared it to other hypopharyngeal surgeries based on success rate. Four of the 5 included studies in the review referenced previously were also included in the present analysis.12,13,28,31 Using the same definition of surgical success, they found that 50% (37/74) of treatments were considered successful, which is slightly less than the success rate found in our study (59.6%). Our success rate is also similar to other multilevel surgeries including genioglossus advancement and hyoid suspension, which at one time was considered first-line therapy for hypopharyngeal obstruction.

The present review was only able to identify 24 subjects treated with glossectomy as sole therapy for OSA.20-22 Despite this small population, initial results are promising. Reduction in ESS score, in particular, compared favorably to other hypopharyngeal surgeries based on success rate.35 The final 5 were given multilevel surgery (UPPP, hyoid suspension, and ESS (9.3) and an increase in LSAT of 17%). Such impressive results were most likely due to strict inclusion criteria, including preoperative CT-confirmed hypopharyngeal airway space <180 mm. This further demonstrates that in such a site-specific sleep surgery, such as UPPP and glossectomy, determination of site obstruction is imperative.

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the 3 studies we used to assess a single glossectomy treatment into account. Although evidence presented here cannot disagree with that statement, it is certainly possible that under the right circumstances and with identification of the correct subjects, glossectomy is an effective single treatment for OSA.

Our study has some important limitations. There is a lack of quality research involving glossectomy with the majority of available published data drawn from small case series without control arms. This has made it difficult to determine the true effectiveness of glossectomy. Similar procedures vary in surgical approach, the inclusion criteria for patient selection, and types of additional procedures, and definitions of and the amount of attention paid to complications in each series, while similar, are not standardized across studies. Additionally, many of the isolated glossectomy patients analyzed received previous palate surgery. This makes it extremely difficult to truly compare treatments and complications. It should also be noted that AHI, while the most popular and universally reported outcome metric used for sleep medicine, has its limitations.37 Future directions for research include further evaluation of isolated glossectomy and direct comparisons of glossectomy to other tongue base surgeries in multilevel surgery.

Conclusion

Our study suggests that glossectomy significantly improves sleep outcomes as part of multilevel surgery in select adult patients with OSA. Currently, there is insufficient evidence to analyze the role of glossectomy as a standalone procedure for the treatment of sleep apnea.

Author Contributions

Alexander W. Murphey, collected data, analyzed data, drafting article, revised article; Jessica A. Kandl, collected data, analyzed data, drafting article; Shaun A. Nguyen, designed study, analyzed and interpreted data, revised article; Aimee C. Weber, collected data, revised article; M. Boyd Gillespie, designed study, interpreted data, drafting article, revised article.

Disclosures

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