Predicting Surgical Response Using Tensiometry in OSA Patients after Genioglossus Advancement with Uvulopalatopharyngoplasty

José E. Barrera, MD¹,²,³,⁴, and Gregory R. Dion, MD, MS¹

Abstract

Objective. To evaluate the role of tension on the genioglossus muscle in the performance of genioglossus advancement on sleep-disordered breathing in patients undergoing multilevel obstructive sleep apnea (OSA) surgery.

Study Design. Prospective study.

Setting. Academic practice.

Subjects and Methods. Twenty-three subjects underwent genioglossus advancement with uvulopalatopharyngoplasty for OSA. Subjects underwent pre- and postoperative polysomnography, cephalometry, and subjective assessment questionnaires. Eighteen subjects completed the study. The tension force of the mandible and the bicortical width of the genial tubercle were measured and surgical response determined.

Results. Improvement in apnea-hypopnea index (AHI) was seen in 15 of 18 subjects (83.3%). Eleven subjects were classified as responders and 7 as nonresponders (61.1% success), with responders exhibiting a statistically significant reduction in mean delta AHI as compared with nonresponders: 28.3 ± 26.2 versus 2.0 ± 22.0 events per hour (95% confidence interval, 1.8-50.8; P = .037). The Epworth Sleepiness Scale improved from 13.2 ± 4.5 to 7.6 ± 3.4 (P = .002). There was no significant difference in body mass index, neck circumference, overall tension, or mandibular width between responders and nonresponders. However, there was a significant difference in the tension:width ratio between responders (53.9 ± 6.38 g/mm) and nonresponders (65.4 ± 11.2 g/mm; 95% confidence interval, 0.92-22.1; P = .036).

Conclusion. This article describes a novel approach to determine the force applied to the genioglossus during advancement and its correlation to postoperative outcomes. The tension:width ratio may be an indicator for postoperative success and delta AHI improvement in OSA patients.

Keywords

obstructive sleep apnea, sleep surgery success, surgical response, tensiometry, genioglossal advancement, uvulopalatopharyngoplasty, force tension, geniotubercle advancement, apnea-hypopnea index, AHI

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Obstructive sleep apnea (OSA) continues to be a pervasive condition that is linked to an increased incidence of cardiovascular diseases, endocrine disorders, and overall increased health care utilization.¹ Genioglossus advancement (GA) for OSA, with or without a palatal procedure, is a proven technique for relieving airway obstruction during sleep.² It has been well established that GA procedures typically accomplish a goal of 8 to 14 mm of advancement based on the bicortical width of the genial tubercle. The bicortical width associated with GA has been noted to increase tension on the genioglossus and geniohyoid muscles with the goal of reducing the severity of sleep apnea.¹,³,⁵ Patients are traditionally selected for surgery based on the level of obstruction, which occurs at the level of the base of tongue, although most patients demonstrate retropalatal obstruction as well. Since the introduction of inferior sagittal osteotomy of the mandible to advance the genioglossus muscle along with uvulopalatopharyngoplasty (UPPP) as described by Riley et al, multilevel reconstruction surgery has demonstrated improved outcomes in relieving OSA in those who demonstrate multilevel obstruction.¹,³,⁵

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Although physical examination, drug-induced sleep endoscopy, and polysomnography (PSG) help to guide the clinician’s decision-making process in selecting patients who are candidates for GA combined with UPPP, intraoperative factors—such as bicortical width of the advanced portion of the mandible and the force required to pull the window osteotomy forward—and their relative effect on postoperative outcomes have not been studied.

The aims of this study are to determine the importance of force applied to the genioglossus muscle during advancement, as well as the width of advancement, and to correlate this information with postoperative outcomes. If this question could be answered satisfactorily, it would be useful to provide immediate prognostic information following surgery and even guide future management decisions.

Methods

Study Design
From February 2010 to January 2011, 23 OSA patients (17 men, 6 women; age range, 22-60 years) from the Department of Otolaryngology–Head and Neck Surgery at the San Antonio Military Medical Center were included in this study. Patients were consecutively selected and prospectively enrolled who had clinically diagnosed OSA and an apnea-hypopnea index (AHI) >5 or respiratory disturbance index (RDI) >20 events per hour by polysomnograph and an Epworth Sleepiness Scale (ESS) >8 and who either did not tolerate or refused a trial of continuous positive airway pressure. All those enrolled demonstrated evidence of obstruction as demonstrated by physical examination and fiberoptic laryngoscopy documenting Friedman II or III classification. Exclusion criteria were as follows: age <18 years, chronic pulmonary disease, and those affected with primary insomnia, parasomnia, and central sleep apnea. Preoperative assessment included history taking, ESS evaluation, body mass index (BMI), neck circumference, complete physical examination, and PSG. Follow-up ranged from 3 months to 3 years. Eighteen patients were reevaluated at 6 months after the surgery with the same preoperative assessment methods. A responder was defined as a >50% reduction in AHI to an absolute level <20 events per hour with no oxygen desaturations on postoperative PSG <85%. Informed consent was obtained from all patients, and the San Antonio Military Medical Consortium research review board approved the research (OI 40A-022). All patients underwent a modified UPPP and GA as described by Barrera et al.3 The modified UPPP was a uvulopalatal flap.

Mandible Width Measurement Technique
The bicortical width of the mandible was measured intraoperatively to assess the thickness of the genial tubercle. The term bicortical width relates to this measurement as the anterior-posterior thickness of the mandibular bone at the genial tubercle (Figure 1). The facial cortex and medullary bone are then removed, and the lingual cortex holding the origin of the genioglossus muscle is rotated perpendicular to the window osteotomy (Figure 2). The osteotomized segment is then secured inferiorly with a single bicortical titanium screw.
Tension Measurement Technique

A monocortical titanium miniscrew was placed at the center of the osteotomized segment to pull the mandibular segment forward. A 26-gauge wire was attached to the screw, and intraoperatively, the force required to pull the window osteotomy forward was measured with a tensiometer per the technique described by Burgess et al. The tension technique via the tensiometer force sensor is reported in grams. Although the official SI unit (International System of Units) for force is Newtons (N), we followed the conventions and traditions of the string industry in using the widely accepted (but non-SI) units of gram-force (g) and kilopond (kp):

\[ 1 \text{ kp} = 454 \text{ g} = 4.448 \text{ N} . \]

A total of 3 measurements were attained with the tensiometer. These data were then averaged to obtain an accurate assessment of the tension force required for adequate GA. The bicortical width of the mandible was measured with a surgical ruler. The facial cortex and medullary bone were then removed, and the lingual cortex holding the origin of the genioglossus muscle was rotated perpendicular to the window osteotomy. The osteotomized segment was then secured inferiorty with a single bicortical titanium screw. There was no muscle relaxant used during the operation.

Postoperative Follow-up

Patients underwent PSG at the earliest 3 months postoperatively, as well as repeat physical examination, ESS, and nasal endoscopy. Data collected from the sleep study and physical examination were then compared against the preoperative data and the intraoperative tensiometry measurements. The collected data were then statistically analyzed with SPSS 19 (IBM Company, Chicago, Illinois). A paired \( t \)-test was used for testing pre- and postoperative AHI for subjects undergoing surgery. A chi-square analysis was used to evaluate responder status as compared with OSA classification (mild, moderate, or severe). Independent \( t \)-tests were used to compare tension, mandibular width, change in AHI per patient (delta AHI), and tension:width ratio. Levene’s test for equality of variances was used to test that an assumption of the \( t \)-test had been met. The \( t \)-test assumes that the variability of each group is approximately equal. Results were considered significant if the resulting \( P \) value was \(< .05\).

Results

Of 23 patients enrolled in the study, 18 completed postoperative PSG and postoperative examinations. Of those patients with completed data sets, 61.1% (11 of 18) were responders, defined as a \( >50\% \) reduction in AHI to an absolute level \(< 20 \) events per hour with no oxygen desaturations on postoperative PSG \(< 85\% \). A positive improvement in AHI was seen in 83.3% (15 of 18) of patients. Table 1 contains a summary of study results.

Of the patients who completed the study, 3 had mild OSA, 7 had moderate OSA, and 7 had severe OSA (Table 2). There was no statistically significant difference between

### Table 1. Patient Variables Measured.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Average BMI, kg/m²</th>
<th>Responder</th>
<th>Tension, g</th>
<th>Width, mm</th>
<th>Ratio, g/mm</th>
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<th>POST</th>
<th>Delta</th>
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<td>28</td>
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<td>723</td>
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</tr>
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<td>R</td>
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<td>17</td>
<td>52.9</td>
<td>29</td>
<td>7</td>
<td>-22</td>
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</table>

Abbreviations: AHI, apnea-hypopnea index; BMI, body mass index; delta, difference in pre- and postoperative AHI; NA, not available; NR, nonresponder; R, responder; PRE, preoperative; POST, postoperative.
the severity of OSA and overall response rates. Analysis of the pre- and postoperative PSG findings showed a statistically significant decrease in AHI following UPPP with GA from $41.1 \pm 29.7$ to $22.9 \pm 29.2$ events per hour (95% confidence interval [95% CI], $4.5-29.5$; $P = .015$) across all groups. RDI also improved from $29.7$ to $22.9$ events per hour among nonresponders (change from $19.9$ to $35.3$ kg/m² ($P = .037$). There was no significant difference in the tension:width ratio between responders and nonresponders. More so, a lower ratio was significantly associated with surgical response in patients. 

Responders exhibited a statistically significant reduction in the mean delta AHI of $28.3 \pm 26.2$ events per hour, resulting in an improvement from $34.3$ to $5.7$ events per hour versus $2.0 \pm 22.0$ events per hour among nonresponders (change from $51.9$ to $49.9$ events per hour; 95% CI, $0.92-22.1$; $P = .036$). There was no significant difference in BMI, neck circumference, overall tension, or mandibular width between responders and nonresponders. Although there was no significant change in BMI comparing responders and nonresponders, the overall cohort had a large BMI increase from $51.9$ to $49.9$ events per hour; 95% CI, $31.6$ kg/m². In addition, patient 10, a nonresponder with severe OSA and nonresponders, the overall cohort had a large BMI gain from $29.7$ to $22.9$ kg/m². However, there was a significant difference in tension:width ratio between responders and nonresponders (65.4 ± 11.2 g/mm; 95% CI, 0.92-22.1; $P = .036$; Table 3).

ESS data were available both pre- and postoperatively in only 12 of the 18 subjects who completed the study. While there was no significant difference in improvement in ESS score between responders and nonresponders, there was an overall statistically significant improvement in ESS for subjects undergoing UPPP with GA from $13.2 \pm 4.5$ to $7.6 \pm 3.4$ ($P = .002$).

None of the patients had mandible fractures or injury of the roots of the incisor teeth. There was no reported pre- or postoperative dysphagia or aspiration or radiographic evidence of silent aspiration. Twelve patients reported mental paresthesias, but this was temporary in all cases. Three patients had wound dehiscence, which healed with conservative management. One patient experienced temporary velopharyngeal insufficiency, which resolved 3 months postoperatively. Of note, this was the only revision UPPP in our series. Of the 7 patients who were nonresponders, 3 underwent maxillary mandibular advancement. All patients who underwent maxillary mandibular advancement responded to phase II surgery with a postoperative AHI <10 events per hour. None of the patients had hema- tomas of the floor of the mouth or aesthetic changes of the chin.

### Table 3. Mean Outcome Variables among Patients.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Responder</th>
<th>Nonresponder</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandible width, mm</td>
<td>11.7</td>
<td>12.3</td>
<td>.692</td>
</tr>
<tr>
<td>Tension, g</td>
<td>673</td>
<td>762</td>
<td>.359</td>
</tr>
<tr>
<td>Tension:width ratio, g/mm</td>
<td>53.9</td>
<td>65.4</td>
<td>.036</td>
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<tr>
<td>Change in apnea-hypopnea index</td>
<td>−28.3</td>
<td>−2.0</td>
<td>.037</td>
</tr>
</tbody>
</table>

### Discussion

Since its introduction by Riley and Powell, a multilevel and phased approach based on the patient’s level of obstruction has increased sleep surgery’s overall success in reducing the severity of OSA. This logical stepwise approach identifies patients who demonstrate retropalatal and/or hypopharyngeal obstruction. GA addresses retropalatal obstruction, and it may be used alone or in combination with other upper airway surgeries, most commonly UPPP. The goal of surgery is to improve airflow around the base of tongue and reduce the number of obstructive events that occur during sleep. Although there have been multiple studies that explore modifications in GA technique, there are no studies that evaluate the role of tension and bicortical width of the mandible and its impact on overall success rates.

The purpose of this study was to explore the potential impact of the force required to move the osteotomized segment of mandible forward to its new position and its relationship to the width of advancement. Statistical analyses of tension and the width of advancement independently did not show statistical significance when compared with postoperative outcomes. This implies that both variables are dependent to each other. Interestingly, when both variables were paired, the tension:width ratio was a predictor of surgical response. There was a significant difference in tension:width ratio between responders and nonresponders. More so, a lower ratio was significantly associated with surgical response in patients.

GA is a simple technique that does not move the teeth or jaw and therefore does not affect the dental bite. The GA is a procedure performed as a solitary hypopharyngeal procedure or in combination with maxillomandibular advancement. The GA technique places the genioglossus under tension, and this tension may be sufficient to keep the base of tongue region open during sleep. Limitations of the technique include the width of the individual’s anterior mandible (mean thickness, 12-18 mm). In addition, existing tongue laxity during sleep factors on how much tension is gained when the genial tubercle is moved. In a flaccid tongue, the movement may all or partially be taken up by the advancement, and little or no improvement may be attained. Tiner and Waite theorized that tension of the genioglossus and genial width were undetermined factors associated with success in genial surgery. A paucity exists in determining the amount of tension needed or the critical distance that the genial tubercle needs to move for effective advancement.
posterior airway space improvement. Our study has determined that the tension:width ratio associated with genioglossal advancement surgery may be an indicator for surgical response in OSA patients. These 2 factors limit our preoperative ability to accurately or consistently predict clinical outcomes.

A meta-analysis evaluated success rates of genioglossal advancement and found them to be between 39% and 78%.11 Results of GA as a sole procedure for treatment of hypopharyngeal obstruction in severe OSA patients has been published, with success >60% in 3 studies and with oxyhemoglobin saturation results in 2 studies showing improvement in low oxyhemoglobin saturation. Only 1 study controlled for BMI, and all 4 studies were level 4 evidence-based medicine. The overall success rate was 62%. Our published clinical outcomes for success rates for genioglossal advancement with UPPP were 61%, with 83% of subjects showing improvement. Other centers have reported similar results with this procedure; however, there are no studies evaluating the physiologic tension and width of the genioglossus muscle and how these measures relate to surgical success. The goal of the study was to evaluate a novel approach to identify patients more likely to respond or improve after surgery based on AHI. Although AHI may not be the best prognostic indicator for sleep surgery, it is widely used in sleep medicine and surgery as the standard for defining OSA severity. More so, an intraoperative tool such as the tension:width ratio may be a simple surgical measure for skeletal procedures to aid in patient counseling and management.

Complications associated with GA include tooth injury or loss, paresthesias, mandibular fracture, difficulty swallowing, wound infection, nonunion, and malunion of the mandible. Evaluation of swallow before and after GA has shown no increased incidence of swallow or speech dysfunction.12

Another limitation of the study is the impact of UPPP on surgical outcome. UPPP may be a separate confounder on surgical response in patients undergoing simultaneous GA in this study. In addition, the nonresponders demonstrated a higher pretreatment AHI in comparison with responders, 51.9 versus 34.3 events per hour. The poorer outcome of nonresponders may be attributed to a higher preoperative AHI. The study design was an open-enrollment prospective study without restriction based on AHI, RDI, or BMI. All mild OSA patients exhibited surgical response based on AHI. Patient 4 was enrolled with an AHI of 3 events per hour secondary to having an RDI of 25.4 events per hour and an ESS of 21. The postoperative AHI decreased to 0.9, RDI to 5.5, and ESS to 9. Overall, the RDI was not significantly different from the AHI, except for this 1 subject. Although nonresponders did have a higher BMI versus that of responders, this result was not significant. The overall cohort had a large average BMI of 31.6 kg/m². Patient 10, a nonresponder with a delta AHI increase of 25 events per hour, had an increase in BMI from 19.9 to 35.3 kg/m² (Table 1). A larger cohort addressing change in the pre- to postoperative BMI may help to reveal the impact of BMI on the successful outcome of this operation.

The study was undertaken in an attempt to isolate the elasticity of the tongue muscles under general anesthesia and without muscle relaxant. Given the nature of the GA procedure, the tension associated with mandibular distraction at the genial tubercle and its associated width were directly measured without manipulating the mouth aperture. With string tension as a proposed mechanism for explaining the effects of the GA on the airway, the tension:width ratio was used as a parameter for defining surgical response. In addition to the genioglossus muscle, the geniohyoid, mylohyoid, and digastric muscle activity may play a role in surgical response after the GA procedure. There are other limiting factors associated with the completeness of the osteotomy—including the preservation of the inferior cortex to 10 mm above the inferior border of the mandible, the height of the mesial ramus osteotomy and how it relates to the incisor tooth roots, and the angle of the osteotomies themselves. These factors may affect the tension obtained during intraoperative measurement. Although the osteotomy was performed perpendicular to the mandible and mesial to the incisor, the amount of genioglossus muscle captured may be affected by slight differences in the osteotomy performed among patients, thus affecting the overall tension measured.

We have noted that the tension:width ratio may be a predictor for surgical response following GA. Our study shows a significant reduction in the mean delta AHI among responders versus nonresponders as delineated by the tension:width ratio.

**Conclusion**

A novel approach is described to determine the force applied to the genioglossus muscle during advancement and its correlation to postoperative outcomes. The tension:width ratio may be an indicator for postoperative success and delta AHI improvement in patients with OSA.

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**Author Contributions**

José E. Barrera, substantial contribution in conception, design, analysis, interpretation and drafting of work; final approval obtained; Gregory R. Dion, substantial contribution in analysis, interpretation and drafting of work; final approval obtained.

**Disclosures**

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**References**


