Modified Hyoid Suspension Technique in the Treatment of Multilevel Related Obstructive Sleep Apnea

Ottavio Piccin, MD¹, Giuseppe Scaramuzzino, MD¹, Chiara Martone, MD¹, Francesca Marra, MD¹, Riccardo Gobbi, MD¹, and Giovanni Sorrenti, MD¹

No sponsorships or competing interests have been disclosed for this article.

Abstract
Objective. Using the Hörmann technique of hyoid suspension in sleep apnea surgery, a steel wire is placed through the thyroid cartilage and slung around the hyoid bone. However, we experienced thyroid cartilage fracture by steel wire traction. A modification is presented to avoid thyroid cartilage fracture.

Study Design. Case series with chart review.

Setting. University hospital.

Subjects and Methods. Twenty-seven patients affected by obstructive sleep apnea syndrome underwent Hörmann hyoid suspension. In 2 patients, the steel wire caused a fracture of the thyroid cartilage. The technique was therefore modified in 25 subsequent patients. The wire is threaded through an adaptation titanium miniplate placed on the surface of the thyroid cartilage.

Results. The apnea-hypopnea index decreased from 43.1 to 10.9/h. Nineteen patients (76%) met the criteria for a successful outcome. No complications related to this modification were noted.

Conclusions. The Hörmann hyoid suspension is a procedure that advances the hyoid bone to expand the airway, and its effectiveness has been proven previously. The modified hyoid suspension presented here promises similar results without the risk of serious complications such as thyroid cartilage fracture.

Keywords
hyoid suspension, obstructive sleep apnea, multilevel surgery

Received May 21, 2013; revised November 1, 2013; accepted November 7, 2013.

The hyoid suspension is a common part of a multilevel surgery concept and is often combined with other procedures such as genioglossus advancement or uvulopalatopharyngoplasty (UPPP) to treat sleep-disordered related breathing. Initially, hyoid suspension was designed so that the hyoid bone was suspended to the inferior border of the mandible using fascia lata. Myotomy of a portion of the infrahyoid musculature was required to enable mobilization and suspension of the hyoid bone. This technique was introduced by Riley et al.³ The same authors later revised the technique by securing the hyoid arch anteroinferiorly to the thyroid cartilage (hyoid-thyroid-pexia) rather than suspending it to the mandible.² This mobilization of the hyoid bone, in the original technique, required myotomy of a portion of the suprahyoid musculature and division of the stylohyoid ligaments. More recently, Hörmann and Baisch³ presented a modified hyoid-thyroid-pexia technique that uses a single wire suture instead of 4 permanent nonresorbable sutures and not dissecting the suprahyoid musculature and the stylohyoid ligaments. Applying this technique, we experienced thyroid cartilage fracture by steel wire traction. A modification of the technique is presented to avoid thyroid cartilage fracture.

Methods
This study was approved by the Institutional Review Board of our hospital (S. Orsola-Malpighi University Hospital). From January 2010 to March 2012, 27 patients were operated on for obstructive sleep apnea syndrome (OSAS) with hyoid suspension as described by Hörmann associates to lateral pharyngoplasty.⁴ In the second and fourth patients of the series, the steel wire caused a delayed fracture of the thyroid cartilage resolved by reoperation. The hyoid suspension technique was therefore modified in 25 subsequent patients. All

¹Department of Otolaryngology Head and Neck Surgery, S. Orsola-Malpighi University Hospital, Bologna, Italy

Part of this article was presented as a poster at the 2011 AAO-HNSF Annual Meeting & OTO EXPO; September 11-14, 2011; San Francisco, California.

Corresponding Author: Ottavio Piccin, Department of Otolaryngology Head and Neck Surgery, S. Orsola-Malpighi University Hospital, via Massarenti 9, 40138 Bologna, Italy.

Email: ottavio.piccin@gmail.com
patients underwent a preoperative sleep study to establish the diagnosis of obstructive sleep apnea (OSA). They then underwent a preoperative clinical examination, fiberoptic pharyngolaryngoscopy, cephalometry, and sleep endoscopy to establish the site and pattern of upper airway obstruction. Moreover, all patients had subjective analysis with the Epworth Sleepiness Scale (ESS) as a measure of daytime somnolence. A postoperative sleep study was performed no sooner than 4 months after surgery. All patients also underwent postoperative assessment of daytime somnolence. The primary efficacy end points were the mean change in the apnea-hypopnea index (AHI) and ESS total score. Secondary effectiveness end points included the mean change for other polysomnographic data, such as the apnea index (AI), oxygen desaturation index (ODI), percentage of sleep time with oxygen saturation below 90% (CT90%), and lowest oxygen saturation (LSaO2). The pre- and postoperative data were compared using Wilcoxon signed-rank tests with SPSS version 16 (SPSS, Inc, an IBM Company, Chicago, Illinois). The Mann-Whitney U test was used to analyze the difference between responders and nonresponders. Statistical significance was established at a value of P < .05.

Surgical Technique

Hyoid suspension is performed under general anesthesia. The cervical incision follows a horizontal skin crease over the hyoid bone. The incision is extended through the subcutaneous tissue and platysma muscle. Upper and lower subplatysmal flaps are elevated to expose the strap muscles. The strap muscles are divided in the midline, exposing the plane of the thyroid cartilage and the surface of the hyoid bone. Following exposure, an adaptation titanium miniplate (2.0 mm; MARTIN, Tuttlingen, Germany) is placed on the surface of the thyroid cartilage (Figure 1). The plate is bent in a 3-dimensional fashion to conform to the laryngeal framework, and the holes are drilled. The screws (self-tapping screws) are inserted, taking care not to apply excessive pull-out force that may strip the threads in the cartilage. The appropriate length of the screws (4-6 mm) is dictated by the thickness of the cartilage. After the fixation is completed, a steel wire with a sharp needle, similar to that used for sternotomy repair, is pierced in through the median upper hole of the miniplate in the anterior surface of the cartilage and pierced out on the contralateral side. Then the steel wire is placed around the hyoid bone (Figure 2). A retractor inserted at the cranial edge of the hyoid bone moves down the hyoid bone in a position ventral to the thyroid cartilage. Finally the 2 ends of the wire are twisted, pinched off, and bent to avoid injuries (Figure 3). A suction drainage is placed for 2 days, and patients receive an intraoperative antibiotic prophylaxis.

Results

All patients had multilevel airway obstruction related to lateral wall collapse as assessed by sleep endoscopy. The patients were all men with a mean (SD) age of 46 (11.8) years. The mean (SD) preoperative body mass index (BMI) was 28.8 (3.7) kg/m² (range, 22.9-33.8), and there was no change postoperatively (mean [SD] BMI, 25.7 [2.3] kg/m²; range, 22.3-33.9; P = .161). Mean (SD) preoperative AHI was 43.1 (25.1) events per hour (range, 10.6-89.1). Almost two-thirds (19 of 25; 76%) of the patients reported excessive daytime somnolence (defined as ESS >10); the mean (SD) value of the ESS was 16 (6; range, 7-20). A postoperative sleep study was performed at a mean of 6.5 months after surgery (range, 4-10 months).

The AHI decreased to a mean (SD) of 10.9 (5.8) events per hour (P < .001). There were similar findings for other polysomnographic parameters (Table 1). Relative to baseline, the AHI decreased by 74.8%. Nineteen (76%) patients achieved a response to treatment, using the most common definition for OSA surgical treatment success: an AHI decrease of ≥50% to <20 events per hour. Nine (36%) had a ≥50% AHI decrease to <15 events/h, 7 (28%) had a
improved significantly (mean [SD], 7.4 [3.2]; $P < .001$). These procedures are performed concurrently or sequentially for the treatment of OSAS, many adjunctive procedures have been proposed and

Discussion

Figure 3. The 2 ends of the wire are twisted, pinched off, and bent to avoid injuries.

$\geq 50\%$ AHI decrease to $< 10$ events/h, and 4 (16%) had a $\geq 50\%$ AHI decrease to $< 5$ events/h. The ESS score improved significantly (mean [SD], 7.4 [3.2]; $P < .001$). Subjects with a BMI $\leq 30$ kg/m$^2$ (56%; 14/25) demonstrated a greater AHI reduction in comparison to the subgroup with a BMI $> 30$ kg/m$^2$. For the subjects with a BMI $\leq 30$ kg/m$^2$, the overall AHI decreased from a mean (SD) of 43.7 (17.4) to 8.7 (13.0) (AHI supine from 53 [26.2] to 29.9 [11.3] and AHI nonsupine from 28.1 [14.3] to 3.2 [9.9]; $P < .001$); for the patients with BMI $> 30$ kg/m$^2$, the overall AHI decreased from a mean (SD) of 48.1 (18.1) to 12.7 (17.0) (AHI supine from 56.9 [31.2] to 34.1 [19.8] and AHI nonsupine from 31.3 [18.5] to 5.6 [11.2]; $P = .002$). There were no statistically significant differences between the 2 subgroups ($P = .62$).

The result of the Mann-Whitney $U$ test showed that age was the only significant factor in predicting success or failure of this kind of surgery (Table 2).

No complications related to this modification were noted.

In view of the limited success of palate surgery in curing OSAS, many adjunctive procedures have been proposed and performed concurrently or sequentially for the treatment of hypopharyngeal airway obstruction. These procedures are based on the idea of a widening and stabilization of the soft tissue and its related airway spaces. Between these techniques, hyoid suspension is indicated in patients with a retrolingual obstruction to avoid more radical surgery, such as maxillomandibular advancement or glossectomy. This procedure, first described by Riley et al in 1986, aims at advancement of the hyoid bone and subsequent increase in the retrolingual space. In 1993, the intervention was modified by fixing the hyoid bone to the thyroid cartilage, instead of fixing it upward to the chin. This modern approach was named hyoid suspension type II or hyoid-thyroid-pexia. The advantages of this revised technique were the lower morbidity (no need to harvest fascia lata) and avoidance of the unfavorable cosmetic changes that could occur after advancement of the hyoid into the submental region. The underlying principle of this procedure is that the hyoid bone is an integral part of the hypopharynx. Anteroinferior movement of the hyoid complex can improve the posterior airway space and avoid obstruction at the tongue base level. The effectiveness of this procedure in conjunction with UPPP has been repeatedly validated. To simplify the surgical procedure, Hörmann and Baisch have presented a modified technique that uses a single wire suture instead of 4 permanent nonresorbable sutures and not dissecting the stylohyoid ligaments. Despite its high effectiveness, this technique was not without complications. Using the Hörmann technique, Tschopp reported the perforation of the pharyngeal mucosa and suggested a modification of the technique by threading a steel wire through a hole drilled in the hyoid bone. In our opinion, this technique could weaken the hyoid bone structure with subsequent fracture. Applying the Hörmann technique, we also experienced thyroid cartilage fracture by steel wire traction, whereas in our modification, the hyoid bone was fixed by a titanium miniplate placed on the surface of the thyroid cartilage, avoiding cartilaginous injury by the tightening of the wire. First postoperative results at our department suggested the high efficacy of this modified hyoid suspension technique, without the risk of serious complications such as thyroid cartilage fracture. We found a cure rate of 76% by using the hyoid suspension as a part of the multilevel surgery concept. Furthermore, as suggested by Stuck et al, we support the idea that hyoid suspension leads to functional effects due to changes in muscle tone and a reduction in soft tissue collapsibility rather than to a relevant active enlargement of the upper airway. For this reason, myotomy of the suprahypopharyngeal musculature should be avoided.

There are certain limitations to the present study. First, this is a retrospective and uncontrolled study, so it lacks patient selection. Moreover, this study is characterized by a limited sample size and, like many studies of multilevel sleep surgery, demonstrates mixed effects that make it difficult to discern the exact contribution of hyoid suspension in the improvement of sleep parameters. Furthermore, although in this report there were no statistically significant differences between responders and nonresponders, the Mann-Whitney $U$ test showed a trend for differences in values for BMI and CT90% (in particular, a difference of 3 points in BMI [27 vs 30] is clinically significant), and so a larger sample size might be able to detect such a difference. In conclusion, the multilevel surgery concept that includes the hyoid suspension by Hörmann has proven its efficacy in the treatment of OSA. The modified hyoid suspension presented here promises similar results without the risk of serious complications such as thyroid cartilage fracture.

Acknowledgments

We thank Valentina Pinto, MD (Department of Plastic and Reconstructive Surgery, S.Orsola-Malpighi University Hospital, Bologna, Italy) for her contribution in preparing the figures.
Table 1. Pre- and postoperative polysomnographic data.

<table>
<thead>
<tr>
<th></th>
<th>Preoperative</th>
<th>Postoperative</th>
<th>P Value</th>
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<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Range</td>
<td>Mean (SD)</td>
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<tr>
<td>AHI per hour</td>
<td>43.1 (25.1)</td>
<td>10.6-89.1</td>
<td>10.9 (5.8)</td>
</tr>
<tr>
<td>AHI supine</td>
<td>55.7</td>
<td>11.4-99.4</td>
<td>33.5</td>
</tr>
<tr>
<td>AHI nonsupine</td>
<td>29.9</td>
<td>0-93.3</td>
<td>4.8</td>
</tr>
<tr>
<td>AI</td>
<td>24.1 (24.7)</td>
<td>3.1-83.4</td>
<td>6.6 (9.9)</td>
</tr>
<tr>
<td>ODI</td>
<td>43.5 (28.2)</td>
<td>3.5-99.6</td>
<td>13.2 (6.9)</td>
</tr>
<tr>
<td>CT90%</td>
<td>18.4 (28.5)</td>
<td>0-86.8</td>
<td>2.4 (18.3)</td>
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<tr>
<td>LSaO2</td>
<td>72.9 (15.2)</td>
<td>57-92</td>
<td>89.2 (5.1)</td>
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</table>

Abbreviations: AHI, apnea-hypopnea index; AI, apnea index; CT90%, time with oxygen saturation less than 90%; LSaO2, lowest oxygen saturation; ODI, oxygen desaturation index.

Table 2. Results of the Mann-Whitney U test.

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Responders (n = 19), Mean (SD)</th>
<th>Nonresponders (n = 6), Mean (SD)</th>
<th>P Value</th>
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<tr>
<td>Age, y</td>
<td>37.2 ± 7.6</td>
<td>51.1 ± 8.3</td>
<td>.01</td>
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<tr>
<td>BMI</td>
<td>27.6 ± 3.6</td>
<td>30.7 ± 2.3</td>
<td>.092</td>
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<tr>
<td>AHI</td>
<td>42.8 ± 16.1</td>
<td>44.1 ± 18.4</td>
<td>.563</td>
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<tr>
<td>LSaO2</td>
<td>73.8 ± 7.6</td>
<td>71.1 ± 5.8</td>
<td>.231</td>
</tr>
<tr>
<td>CT90%</td>
<td>17.9 ± 10.9</td>
<td>18.7 ± 11.3</td>
<td>.064</td>
</tr>
<tr>
<td>ESS</td>
<td>15.8 ± 4.1</td>
<td>16.6 ± 4.4</td>
<td>.674</td>
</tr>
</tbody>
</table>

Abbreviations: AHI, apnea-hypopnea index; BMI, body mass index; CT90%, time with oxygen saturation less than 90%; ESS, Epworth Sleepiness Scale; LSaO2, lowest oxygen saturation.

Author Contributions

Ottavio Piccin, conception and design, drafting the article, analysis and interpretation of data, final approval; Giuseppe Scaramuzzino, analysis and interpretation, drafting, final approval; Chiara Martone, acquisition of data, drafting, final approval; Francesca Marra, acquisition of data, drafting, final approval; Riccardo Gobbi, acquisition of data, drafting, final approval; Giovanni Sorrenti, conception and design, revising, final approval.

Disclosures

Competing interests: None.
Sponsorships: None.
Funding source: None.

References