The Laryngoscope
Lippincott - Raven Publishers, Philadelphia

A Cost-Effectiv and Rational Surgical Approach to Patients With Snoring, Upper Airway Resistance Syndrome, or Obstructive Sleep Apnea Sydrome

David S. Utley, MD; Edward J. Shin, BA; Alex A. Clerk, MD; David J. Terris, MD

The past decade has seen several innovations in the surgical techniques available for treatment of patients with sleep-disordered breathing. Outpatient techniques such as laser-assisted uvulopalatoplasty (LAUP) and more aggressive procedures designed to address hypopharyngeal and base of tongue obstruc¬tion (genioglossus advancement and hyoid myotomy) have been developed and proven successful We de¬scribe the efficacy of LAUP for snoring (72.7%), upper airway resistance syndrome (81.8%), and mild (mean [*SD] respiratory disturbance index [RDI] = 12 * 8.1) obstructive sleep apnea (41.7%) in 56 patients who un¬derwent 132 LAUP procedures in a 26-month period. Thirty-two patients with more significant obstructive sleep apnea (mean RIM = 41.8 ± 23.1) underwent mul¬tilevel pharyngeal surgery consisting of genioglossus advancement and hyoid myotomy combined with uvulopalatopharyngoplasty. The surgical success rate in this group of patients was 85.7% when commonly accepted criteria were applied. We recommend a stratified surgical approach to patients with sleep¬disordered breathing. Progressively worse airway ob¬struction marked by multilevel pharyngeal collapse and more severe sleep-disordered breathing is treated with incrementally more aggressive surgery addressing multiple areas of the upper airway.

Laryngoscope, 107.726-734,1997

INTRODUCTION

Sleep-disordered breathing (SDB) encompasses a wide spectrum of disease severity. At one end of the spectrum is primary snoring without arousals, oxygen desaturations, or significant changes in intrathoracic pressure. At the other end of the spec¬trum is severe obstructive sleep apnea syndrome (OSAS) with frequent arousals, severely disrupted sleep architecture, frequent apnea-hypopnea events, abnormally negative intrathoracic pressures, and excessive daytime somnolence (EDS). Intermediate between these two extremes are milder forms of OSAS, as well as the recently described upper air¬way resistance syndrome (UARS). Patients with UARS have arousals during sleep related to an ab¬normally increased work of breathing and increased upper airway resistance, yet the respiratory distur¬bance index (RDI) may remain normal. These arousals commonly result in symptoms of EDS.[1,2]

Although surgical intervention is one of the well-recognized treatments of SDB, there is contro¬versy as to which of the surgical approaches is most appropriate. Uvulopalatopharyngoplasty (UPPP), first described in 1964 by Ikematsu3 for treatment of snoring, was later found to be an effective, accept¬able alternative to tracheostomy in patients with OSAS.4 In unselected patients with OSAS, however, reported success rates vary from 0% to 90%.5 In their extensive meta-analysis of 37 published re¬ports on UPPP, Sher et al.5 reported the overall suc¬cess of UPPP for OSAS to be 40.7% when success was defined as a greater than 50% drop in apnea in¬dex (AI) or RDI and a postoperative AI of less than 10 or a postoperative RDI of less than 20. The high failure rate that this implies may be explained by the likelihood of upper airway collapse at sites other than the palate.

A multilevel, pharyngeal surgical approach con¬sisting of UPPP, mandibular osteotomy with ge¬nioglossus advancement (GA), and hyoid myotomy with advancement (HM) has been proposed by Riley et al.6,7 They reported a 60% success rate (RDI decreased

From the Division of Otolaryngology-Head and Neck Surgery (D.S.U., E.J.S., D.J.T.) and the Stanford University Sleep Disorders and Re¬search Clinic (A.A.C.), Stanford University Medical Center, Stanford, California.

Presented at the 99th Meeting of the American Laryngological, Rhi¬nological and Otological Society, Inc., Orlando, Florida, May 8, 1996.
Send Reprint Requests to David J. Terris, MD, Division of Otolaryn¬gology-Head and Neck Surgery, R-135, Edwards Building, Stanford Uni¬versity Medical Center, Stanford, CA 94305-5328, U.S.A.

by more than 50% and a postoperative RDI of less than 20, or a result equivalent to the continuous positive airway pressure [CPAP] polysomnogram) for this combined procedure.

The role of laser-assisted uvulopalatoplasty (LAUP) in the management of OSAS or UARS is less clear. LAUP has some degree of efficacy in treating OSAS, as documented by several recently reported success rates of 38.5% to 86.9% The patients in one of these studies were selected for having predominantly velopharyngeal collapse. In each report, some pa¬tients had worsening of their OSAS after LAUP 8--10

Most prior investigations of the surgical management of patients with SDB have concentrated on the evaluation of a single intervention, for example, LAUP, UPPP, GA, HM, or nasal surgery. Because cause SDB is composed of patients with a wide spec¬trum of disease severity, we propose a surgical approach for the management of SDB that involves increasingly aggressive surgery for incrementally more severe SDB and multiple levels of pharyngeal collapse. This approach acknowledges the varied costs of the surgical procedures, the incremental surgical risk, and the likelihood of success of each technique in ameliorating SDB.

MATERIALS AND METHODS

A retrospective review of the patients referred to the Stanford University Medical Center Division of Otolaryn¬gology-Head and Neck Surgery between November 1, 1993, and December 31, 1995, for evaluation of SDB was performed. The preoperative evaluation included a thor¬ough history (focusing on the symptoms of OSAS, includ¬ing EDS), complete head and neck examination, flexible fiberoptic nasopharyngoscopy with a modified Muller ma¬neuver, the Epworth Sleepiness Scale (ESS) question¬naire, and polysomnography. A lateral cephalometric ra¬diograph and panoramic radiograph of the mandible were also obtained for patients who were considered candidates for multilevel pharyngeal surgery.

Modified Muller Maneuver

The modified Muller maneuver was performed with the patient in a sitting position as described by Sher et a1.16 The degree of collapse was graded separately at the retropalatal area, the lateral pharyngeal walls, and the base of tongue as follows: 0 for no collapse, 1+ for a 25% reduction in cross-sectional area, 2+ for a 50% reduction in area, 3+ for a 75% reduction in area, and 4+ for com¬plete obstruction. A single examiner (D.J.T.) was responsi¬ble for all preoperative and postoperative evaluations. The examiner was blinded to the polysomnography data at the time of both preoperative and postoperative modi¬fied Muller maneuver. Differences between preoperative and postoperative modified Muffler maneuver data were assessed using the paired Student's t-test for means.

Epworth Sleepiness Scale

The ESS questionnaire determines the likelihood of dozing in each of eight situations, from highly soporific situations (lying down) in the afternoon) to much less so¬porific ones (talking to someone). The patient rates each situation from 0 to 3, with 3 being the highest likelihood, giving a total range of scores from 0 to 24. A score of less than 7 is considered within normal limits, and a score greater than 9 is suggestive of SDB.17 Differences between preoperative and postoperative ESS data were assessed using the paired Student's t-test for means.

Polysomnography

The patients were evaluated preoperatively and then at least 4 months postoperatively by polysomnography. Patients had either an attended in-hospital study or am¬bulatory polysomnography. The attended study consisted of nocturnal polygraphic monitoring, including electroen¬cephalogram (C3/A2 and 02/Al electrodes of the interna¬tional electrode placement system), electrooculogram, chin and leg electromyogram, and electrocardiogram (modified V2 lead), and intraesophageal pressure monitor¬ing. Respiration was investigated by oronasal airflow, tho¬racic and abdominal movements (inductive plethysmography), snoring sounds (subminiature electric microphone type MCE-2000 [ME-SAM-4 equipment, Conrad Electron¬ics, Hirchau, Germany] taped above the larynx), and oxy¬gen saturation (pulse oximetry). Records were scored fol¬lowing the criteria of Rechtschaffen and Kales18 for sleep/wake determination, and the criteria for determin¬ing other sleep syndromes were based on the interna¬tional classification of sleep disorders. 19 Abnormal breath¬ing patterns were scored using the current criteria for identifying sleep apnea and sleep hypopnea.20,21
Ambulatory polysomnography studies were per¬formed with an Edentec portable device (Edentec Moni¬toring System, model 4700 Scanner, Eden-Prarie, MN) measuring nasal and oral airflow (thermistry), chest wall impedence, oxygen saturation (finger pulse oximetry), heart rate, and movement. Respiratory events were scored using similar criteria as used for in-hospital polysomnography.22 Differences between preoperative and postopera¬tive polysomnography data were assessed using the paired Student's t-test for means.

Surgery

Patients with primary snoring or UARS were encour¬aged to undergo LAUP Those with mild OSAS (a RDI of more than 5 but less 20, without significant oxygen desaturation) were encouraged to undergo LAUP or UPPP de¬pending on their preference. If these patients demon¬strated significant preoperative lateral pharyngeal or base of tongue collapse on the modified Muller maneuver, they were offered multilevel pharyngeal surgery as a more aggressive alternative to LAUP or UPPP alone. Pa¬tients with moderate (RDI >_20 and <40) or severe (RDI >_40) OSAS usually had multiple sites of obstruction and were offered multilevel pharyngeal surgery. The patients with more severe OSAS were referred for continuous pos¬itive airway pressure (CPAP), to expeditiously treat their OSAS and so that CPAP was available for the perioperative period. A small number of patients with moderate or severe OSAS who already had CPAP requested treatment with LAUP alone. In all cases, patients with significant nasal obstruction were treated with topical nasal corticosteroids and, in the event of treatment failure, were offered a septoplasty with turbinate reduction. The "nasal spray test" as described by Fairbanks23 (patients use intranasal decongestant spray on alternate nights for 1 week and then compare snoring on spray and nonspray nights) was useful in choosing appropriate surgical candidates.

A standard technique for UPPP was used as de¬scribed originally by Fujita et al .4 and Simmons et al." Standard septoplasty was performed in a subset of patients and was combined with resection of approximately 50% of each inferior turbinate as described by Goode.24

The LAUP procedures were performed with a Luxar LX-20 C02 laser (Bothel, WA) at a setting of 20 W, contin¬uous mode. Uvular and palatal reduction was performed, as were bilateral vertical trenches through the palate (Fig. 1) and ablation of tonsils, when present. The patients received perioperative antibiotics (amoxicillin, 250 mg three times daily for 7 days) and perioperative corticosteroids (methylprednisolone, dispensed as a 6-day Medrol Dosepak). The number of stages ranged from 1 to 5, with each stage separated by a minimum of 4 weeks.

Multilevel pharyngeal surgery comprised three pro¬cedures (UPPP, GA, and HM) performed during a single operation as described by Riley et al.,7 using the modifi¬cation in which a window is created in the mandibular symphysis to incorporate the genial tubercle, instead of an inferior sagittal osteotomy, and a second modification in which the hyoid is advanced over the thyroid laminae, instead of being suspended from the inferior mandibles (Fig. 2).

RESULTS

Of 229 patients who were evaluated in the Stanford University Medical Center Division of Oto¬laryngology-Head and Neck Surgery between No¬vember 1, 1993, and December 31, 1995, for treat¬ment of snoring, OSAS, and/or EDS, 95 were determined to be candidates for surgical treatment. The remaining 134 patients either chose nonsurgi¬cal interventions (including CPAP, dental appli¬ances, or behavioral modification) or refused con¬ventional treatment. Twenty-one of 95 patients (22.1%) underwent a trial of CPAP prior to surgery. In addition, most patients with severe OSAS (RDI >_40, lowest oxygen saturation [LSAT] <75%) were prescribed CPAP perioperatively. Although all pa¬tients were encouraged to consider CPAP, in most cases this trial was undertaken to comply with in¬surance guidelines.

Laser-Assisted Uvulopalatoplasty

Fifty-six patients (50 men, 6 women; mean [±SD] age 45.3 ± 11.3 years) were considered candi¬dates for LAUP This group had a mean ESS score of 8.5 ± 5.6, a mean RDI of 12.1 ± 14.5 (mean AI = 5.5 t 10.9; mean hypopnea index = 6.8 ± 8.6), and a mean LSAT of 87.9 ± 5.7%, and all patients snored. The degree of palatal collapse noted on the modified Muller maneuver was 2.2 ± 1.3. A total of 134 LAUP procedures were performed on these 56 patients (mean per patient, 2.4 ± 1; range, 1 to 5). Of the 47 patients in whom preoperative and postoperativeESS data were available, the mean score fell from 8.9 ± 6 to 6.6 ± 4.5 (P = 0.041). Full preoperative and postoperative (polysomnography) data were avail¬able for 12 of these patients. Preoperatively, 10 had attended studies and 2 had ambulatory studies. Postoperatively, 5 had attended studies and 7 had ambulatory studies. In 4 (33%) of these 12 patients, the RDI was reduced by more than 50%, and the postoperative RDI was less than 20. Application of the response criteria defined by Sher et al.5 (>50% drop in AI or RDI, with a postoperative AI of less than 10 or a postoperative RDI of less than 20) re¬sulted in a success rate of 41.7% (5 of 12 patients). However, the overall mean parameters showed slight worsening (Table I).

All patients for whom snoring data were avail¬able (55 of 57) reported an improvement in the vol¬ume and frequency of snoring. This was a subjec¬tive determination based on interviews of the patient and sleep partner that were conducted at least 4 weeks after surgery. Patients were asked whether the snoring volume had changed and to what degree, and if the snoring occurred less fre¬quently each night or on fewer nights per week. Snoring was completely cured in 23 patients (41.8%), 50% to 99% improved in 28 (50.9%), and less than 50% improved in 4 (7.3%). Overall, 72.7% of patients had greater than 70% improvement in their snoring.

Preoperative and postoperative modified Muller maneuver data were available for 18 patients, with palatal collapse decreasing from 2.5 ± 1.3 to 0.9 ± 1.3 (P < 0.001). No significant change was seen in collapse of the lateral pharyngeal walls or the base of tongue (Table I). One vasovagal episode occurred during LAUP and was successfully treated with con¬servative measures. One patient had postoperative palatal bleeding requiring electrocautery in the of¬fice. There were no major complications.

Of the 56 patients who underwent LAUP, 11 were diagnosed with UARS (minimal esophageal pressure [Peg] <-20 mm Hg; RDI <10; and ESS >_7).1,2 Of these patients, 81.8% reported improve¬ment in EDS symptoms as evidenced by improved ESS scores from 13.5 ± 4.4 to 8 ± 2.5 (P = 0.002).

Multilevel Pharyngeal Surgery

Thirty-two patients underwent multilevel pha¬ryngeal surgery consisting of UPPP, GA, and HM (30 men, 2 women; mean age, 46.1 ± 11 years; mean body mass index [BMI] = 31.1 ± 4.8). Nine of these patients also underwent septoplasty and bilateral inferior turbinate resection 1 month after UPPP/ GA/HM. The demographic, polysomnography, and anatomic data for the entire group are indicated in Table II. All patients snored. Of the patients in whom preoperative and postoperative ESS scores were available (29 of 32), the mean score fell from 12.1 ± 4.9 to 4.5 ± 4.1 (P < 0.001). Preoperative and postoperative polysomnography data were available for 14 of these patients. Preoperatively, 13 had

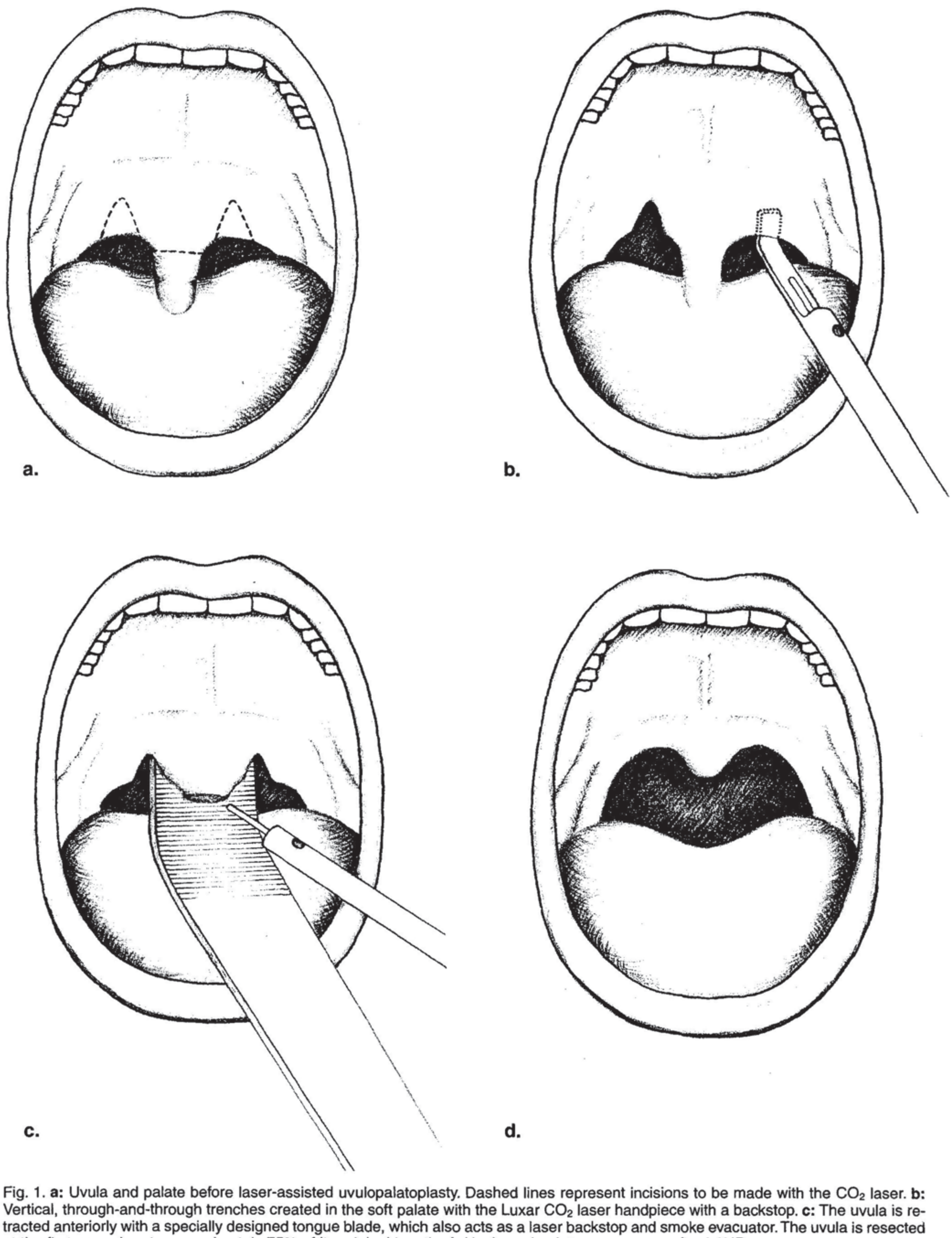

Fig. 1. **a:** Uvula and palate before laser-assisted uvulopalatoplasty. Dashed lines represent incisions to be made with the CO_2 laser. **b:** Vertical, through-and-through trenches created in the soft palate with the Luxar CO_2 laser handpiece with a backstop. **c:** The uvula is retracted anteriorly with a specially designed tongue blade, which also acts as a laser backstop and smoke evacuator. The uvula is resected at the first procedure to approximately 75% of its original length. **d:** Uvula and palate appearance after LAUP.

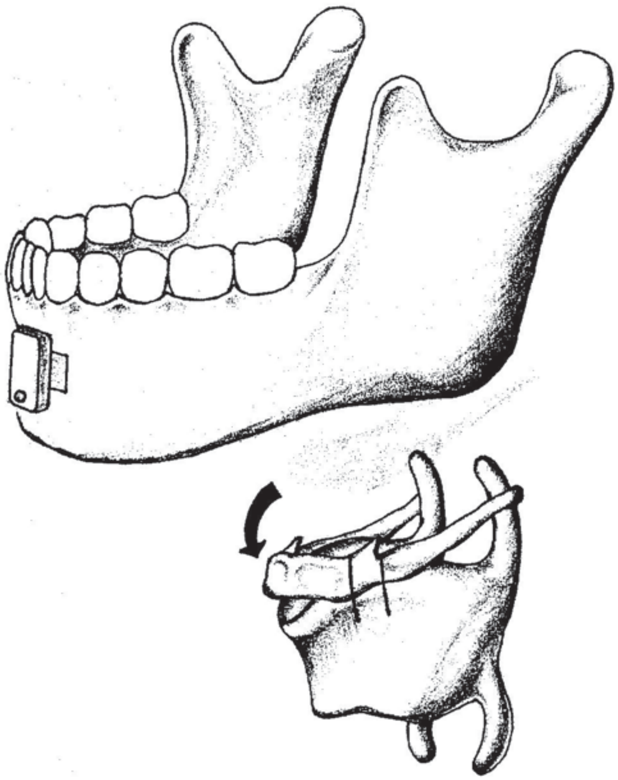

Fig. 2. Diagram of mandibular osteotomy, genioglossus advance¬ment, and hyoid myotomy and suspension. The osteotomized mandibular segment is advanced and turned 90°, the outer cor¬tex and marrow are removed, and the segment is secured with a titanium screw. The infrahyoid musculature is divided, as is the stylohyoid ligament. The hyoid bone is advanced over the thyroid laminae and secured with four nonabsorbable sutures.

attended studies and 1 had an ambulatory study. Post¬operatively, 12 had attended studies and 2 had am¬bulatory studies. The RDI decreased in 92.9% of these patients (13 of 14), and 57.1% (8 of 14) were considered a success by having a reduction in RDI of more than 50% and a postoperative RDI of less than 20. Application of the response criteria defined by Sher et al.5 (>50% drop in AI or RDI, with a postop¬erative AI <10 or a postoperative RDI <20) yielded a success rate of 85.7% (12 of 14 patients). The mean preoperative and postoperative data for this sub¬group are detailed in Table II. The improvement in RDI (P = 0.011) and AI (P = 0.006) was statistically significant. All patients in the UPPP/GA/HM group for whom snoring data were available (24 of 32) re-ported an improvement in the volume and fre¬quency of snoring; it was completely cured in 12 pa¬tients (50%), 50% to 99% improved in 10 (41.7%), and 25% or less improved in 2 (8.3%). Nineteen of 24 patients (79.2%) had greater than 70% improve¬ment in snoring.

Preoperative and postoperative modified Muller maneuver data were available for 21 of the 32 patients. The mean palatal collapse decreased from 3.3 ± 1 to 0.8 ± 0.9 (P < 0.001), the mean lat¬eral pharyngeal wall collapse decreased from 2.5 ± 1.1 to 1.5 ± 1.1 (P < 0.05), and the mean base of tongue collapse decreased from 1.9 ± 1.4 to 0.7 t 1.2 (P < 0.05).

Complications included five gingivolabial sulcus incision dehiscences (all healed spontaneously), two extruded screws and mandibular bony seg¬ments (one required operative management), one case of moderate ecchymosis and edema of the neck and face skin without airway compromise, and one gingivolabial sulcus wound infection that resolved with local wound care and antibiotics. All patients reported transient paresthesia of the mandibular incisors that resolved after 3 months.

Septoplasty and Inferior Turbinate Resection

Six patients underwent septoplasty and bilat¬eral inferior turbinate resection (five men, one woman; mean age, 48.8 ± 11.1 years; mean BMI, 29.8 t 6.2). ESS scores for four of the six patients worsened or remained unchanged, but the overall mean score decreased from 7.8 ± 5.2 to 6.8 ± 5.4 (P = 0.56). There was one case of surgical success for OSAS (50% reduction in RDI and RDI <20), but the overall mean RDI increased from 11.4 ± 4.9 to 20.7 ± 16 (P = 0.24) (Table III). Two of the six patients re¬ported an improvement in the volume and fre¬quency of snoring; it was completely cured in one patient (16.7%) and 50% to 99% improved in the other (16.7%). No complications were experienced.

The remaining seven patients had various proce¬dures consisting of UPPP alone or in combinations with septoplasty, turbinate resection, or adenoidectomy. The heterogeneity of this group prevented meaningful analysis of the results.

Costs

Costs for various surgical procedures directed at treating SDI vary widely between institutions. The estimated charge, however, for complete treat¬ment of snoring with LAPP is $2500. A UPPP with a single-night, inpatient hospitalization would incur a charge of approximately $10,600. Because of the need for one night in the intensive care unit and one night on the ward, the charge for UPPP/GA/HM is estimated to be $28,000. The approximate charge for outpatient septoplasty and bilateral turbinate trim is $9600. The above estimates include anesthesia fees, surgeon fees, and operating room and hos¬pital charges where applicable. Reimbursement is considerably lower than the charges.

TABLE I.
Laser-Assisted Uvulopalatopharyngoplasty.

	All Patients		Available Data		
	Preoperative	No.	Preoperative	Postoperative	No.
Age (y)	56 ± 11.3	52			
Body mass index (kg/m²)	86.2 ± 15.6	51	28.4 ± 5.1	27.9 ± 5.3	42
Epworth Sleepiness Scale score	8.5 ± 5.6	56	8.9 ± 6	6.6 ± 4.5	47
Respiratory disturbance index	12.1 ± 14.5	51*	8.9 ± 6.1	10.3 ± 8.1	12
Apnea index	5.5 ± 10.9	46*	2 ± 2.7	2.3 ± 2.4	12
Hypopnea index	6.8 ± 8.6	46*	5.8 ± 3.5	8 ± 7.1	12
Lowest oxygen saturation (%)	87.9 ± 5.7	55*	86 ± 7.2	88.6 ± 6.5	12
Mean maximum negative intrathoracic pressure (mm Hg)	−36 ± 17.8	19	−50 ± 5.3	−44.7 ± 6.4	3
Mean apnea duration (sec)	16.5 ± 9.9	43	16 ± 7.6	11.6 ± 9.3	10
Maximum apnea duration (sec)	23.8 ± 17.4	34	17.8 ± 12.7	10.2 ± 15.3	5
Mean hypopnea duration (sec)	17.1 ± 6	44	18.5 ± 8.7	19.5 ± 5.1	8
Maximum hypopnea duration (sec)	29.8 ± 14.8	35	39.8 ± 21.9	26.3 ± 10.3	4
Stage III–IV sleep (%)	8.5 ± 5.9	32	11.1 ± 7	13.2 ± 9	4
Rapid eye movement sleep (%)	16.9 ± 5.7	33	17.5 ± 4.8	15.7 ± 7.3	4
Sleep latency (min)	17.2 ± 15.8	37	26.8 ± 26.4	17.7 ± 26.9	5
Sleep efficiency (%)	83 ± 14.9	37	84.2 ± 7.2	86.6 ± 9.6	5
Modified Müller maneuver					
Palate	22.2 ± 1.3	39	2.5 ± 1.3	0.9 ± 1.3	18
Lateral pharyngeal walls	1.7 ± 1	38	1.8 ± 0.9	1.7 ± 0.9	18
Base of tongue	1.1 ± 1.3	39	1 ± 1.4	0.7 ± 1.2	18

*In a small number of patients, portions of the polysomnogram were incomplete, allowing only approximation of disease severity.

DISCUSSION

Since its description more than 25 years ago, SDB has been the focus of increasingly intense clinical and basic research. The protean manifestations of OSAS include snoring, hypertension, coronary artery disease, cerebrovascular disease, cerebral is-chernia, cardiac arrhythmias, and sudden death.[25-28] The consequences of significant daytime somnolence (usually the index symptom of UARS and mild OSAS) may include diminished cognitive function, decreased work productivity, impotence, and significantly increased risk of accident-related injuries and fatalities in drivers and heavy machinery operators.[29]

Because SDB comprises a spectrum of syndromes with incremental severity, it seems appro¬priate to devise a treatment algorithm that incorporates interventions that have an incremental degree of aggressiveness and associated morbidity and risk. The costs and risks associated with nonsurgical treatments for SDB such as weight loss, avoidance of sedatives and alcohol, and body positioning are negligible; therefore these measures should always be discussed with patients with SDB. Dental appli-ances, while sometimes costly, have low risk and may be considered. The best nonsurgical treatment, however, is nasal CPAP Patients who refuse CPAP or who are unable to tolerate it should be presented with surgical options that are commensurate with the disease severity.

In evaluating patients who have had surgical management of SDB, we have relied heavily on polysomnography for determining success. Indeed, many authors report postoperative success as an improvement in RDI or AI of greater than 50% and a postoperative RDI of less than 20 (or AI <10), or a polysomnography result equal to that when the patient is on a regimen of CPAP[5,7,9,30] However, the value of a lowered RDI in a patient with mild SDB and "success" based on these criteria may not be as significant as a reduction in daytime somnolence to a level that will prevent a fatigue-related motor ve-hicle accident. While the longitudinal study by He et al.21 established that untreated moderate SDB (AI >20) represents an important independent risk factor for morbidity and mortality, the significance of mild SDB (e.g., RDI between 5 and 20) is less clear. Therefore we emphasized the importance of improvement of EDS after each surgical approach, as represented by a reduction in the ESS score. The ESS is a reliable, economical alternative to the mul¬tiple sleep latency test for evaluating EDS, has high test-retest reliability, can help to differentiate snoring from more severe SDB, and may help to diag¬nose UARS in patients who may otherwise go unde¬tected with some types of sleep testing[17] For patients who demonstrate substantially improved ESS scores,

TABLE II.
Multilevel Pharyngeal Surgery

	All Patients		Available Data		
	Preoperative	No.	Preoperative	Postoperative	No.
Age (y)	46.1 ± 11	32			
Body mass index (kg/m²)	31.1 ± 4.8	32	31.1 ± 5	29.7 ± 4	29
Epworth Sleepiness Scale score	11.6 ± 5.2	32	12.1 ± 4.9	4.5 ± 4.1	29
Respiratory disturbance index	41.8 ± 23.1	32	46.6 ± 18.8	22.3 ± 22.3	14
Apnea index	24.7 ± 21.3	30	27.4 ± 22	13.7 ± 25	14
Hypopnea index	14.4 ± 11.4	30	13.3 ± 13	11.3 ± 7.9	14
Lowest oxygen saturation (%)	76.9 ± 11.1	32	76.1 ± 11.2	81.3 ± 11	14
Mean maximum negative intrathoracic pressure (mm Hg)	−52.3 ± 30.3	15	−57.7 ± 37.5	−50 ± 24.8	6
Mean apnea duration (sec)	26.7 ± 11.2	27	30.3 ± 14.4	24.5 ± 17	10
Maximum apnea duration (sec)	71.9 ± 87.7	24	100.1 ± 127.4	46.8 ± 39.2	10
Mean hypopnea duration (sec)	19.1 ± 8.4	24	25.1 ± 7.8	23.7 ± 10.7	7
Maximum hypopnea duration (sec)	41.3 ± 30.7	21	56.1 ± 41.2	51.1 ± 37.2	7
Stage III–IV sleep (%)	4.5 ± 5.9	19	2.1 ± 3.9	4.8 ± 3.4	7
Rapid eye movement sleep (%)	10.9 ± 6.1	18	9.8 ± 6.3	12.6 ± 5.3	7
Sleep latency (min)	14.9 ± 13.7	22	13.7 ± 13.8	6.9 ± 4.5	6
Sleep efficiency (%)	83.2 ± 10.2	23	81.1 ± 14.3	90.1 ± 7.2	6
Modified Müller maneuver					
Palate	2.7 ± 1.1	27	3.3 ± 1	0.8 ± 0.9	21
Lateral pharyngeal walls	2.3 ± 1	27	2.5 ± 1.1	1.5 ± 1.1	21
Base of tongue	2 ± 1.1	27	1.9 ± 1.4	0.7 ± 1.2	21

increased upper airway dimensions, and improved snoring, despite minimal improvement on sleep testing or insufficient improvement to be considered a surgical success, consideration should be given to the potential night-to-night variability of polysomnography results. This degree of variability may be derived from interob¬server differences in scoring,[32] the "first-night" effect,[33] or variability in sleep position, alcohol use, or nasal congestion.[22]

Although there is bias built into any retrospective study, especially when subjective assessments are employed, we believed that the preoperative and postoperative modified Muller maneuver evaluation of the upper airway anatomy provided an important adjunct to the ESS and polysomnography. The examiner in the present study knew whether patients were in the presurgical or postsurgical period but was not aware of polysomnography data while grading collapse preoperatively or postoperatively, thereby minimizing bias. The modified Muller ma¬neuver was particularly valuable when the multi-level pharyngeal surgical approach was assessed; those patients who were cured had more severe pre-operative collapse of the upper airway and a greater improvement in modified Muller maneuver scores postoperatively.

Our analysis confirmed that LAUP is an effective tool for the treatment of primary snoring, with 72.7% of patients reporting significant improvement (70%) of snoring. These results compare favorably with the greater than 70% resolution of snoring in 60% to 71% of patients reported by others.[10,15]LAUP has not completely replaced UPPP for treatment in patients with this mildest form of SDB, but it re¬mains an excellent alternative, since it can be per¬formed in a cost-effective manner (approximately one fourth the cost of UPPP) in an office-based set¬ting using local anesthesia, without the need for hospital admission.

The effectiveness of LAUP in the treatment of UARS was confirmed by improvement in EDS symptoms as evidenced by significantly reduced postoperative ESS scores. Guilleminault et al.[1] recommended against the use of CPAP for the treatment of UARS and indicated that surgical management was desirable. Although our number of patients is too small to draw firm conclusions, it appears that LAUP is an appropriate surgical approach for patients with UARS.

Our experience with LAUP for OSAS, however, confirmed the limitations of single-level pharyngeal surgery for a disease that is often manifested by multilevel pharyngeal obstruction. Despite improvement in snoring and ESS scores for this group as a whole

TABLE III.
Septoplasty and Inferior Turbinate Resection.

	All Patients		Available Data		
	Preoperative	No.	Preoperative	Postoperative	No.
Age (y)	48.8 ± 11.1	6			
Body mass index (kg/m²)	29.8 ± 6.2	6	29.8 ± 6.2	29.4 ± 6.7	6
Epworth Sleepiness Scale score	7.8 ± 5.2	6	7.8 ± 5.2	6.8 ± 5.4	6
Respiratory disturbance index	19.7 ± 19	6	11.4 ± 4.9	20.7 ± 16	4
Apnea index	16.2 ± 20	5	5.6 ± 4.6	8.7 ± 5	4
Hypopnea index	5.9 ± 2.3	5	6.3 ± 2.3	18.3 ± 7.1	4
Lowest oxygen saturation (%)	81 ± 6	6	83 ± 3.8	80.5 ± 11.4	4
Mean maximum negative intrathoracic pressure (mm Hg)	−65 ± 28.6	3	NA	NA	
Mean apnea duration (sec)	32.1 ± 11.6	5	NA	NA	
Maximum apnea duration (sec)	73 ± 23.9	3	NA	NA	
Mean hypopnea duration (sec)	24.9 ± 3.2	3	NA	NA	
Maximum hypopnea duration (sec)	36 ± 4	3	NA	NA	

NA = not available.

our polysomnography success rate (41.7%) is similar to that reported for UPPP, and since we failed to reproduce the remarkable results achieved by other authors,8 we continue to advocate LAUP primarily for patients with mild OSAS (RDI <20, LSAT > 85%) or for patients who refuse any other type of therapy. Therefore patients should under¬stand the limitations of this procedure, and physi¬cians should recognize the potential surgical risks, which include immediate postoperative worsening of the SDB34 and the potential for long-term wors¬ening of OSAS in some patients.9,10 For this reason and for the purpose of evaluating treatment out¬come,5 all patients should have preoperative and postoperative polysomnography.

Multilevel pharyngeal surgery (as described originally by Riley et al 5.7) was the most effective surgical approach for patients with OSAS in our re¬view, as assessed by improvements in polysomnog¬raphy, ESS, and upper airway dimensions. A success rate of 85.7%, using the criteria set forth by Sher et al.5, fell to 57.1% when improvement in only RDI was considered, and this compares favorably with previous reports.? Our group of patients reported dramatic improvements in daytime somnolence as demonstrated by a decrease in mean ESS scores from 12.1 to 4.5. There was also marked improve¬ment in the upper airway dimensions as measured by the modified Muller maneuver, especially at the level of the palate and the base of tongue. The pa¬tients who underwent this more aggressive surgery manifested the most severe degree of preoperative sleep disturbance and EDS; therefore we believe that the increased cost and potential operative mor¬bidity were justified. Because the anatomic obstruc¬tion associated with SDB may occur at multiple sites and in severe cases usually does, it is logical to focus the surgical "attack" to address each of these sites.

There appears to be little role for septoplasty with bilateral inferior turbinate resection as the pri¬mary surgical modality in the management of SDB. In our small series the ESS scores worsened in two thirds of the patients, snoring improved in only one third, and only one of three patients (33.3%) achieved a significant reduction in RDI. However, because increased nasal resistance may contribute to the various degrees of SDB12 and because de¬creased nasal resistance reduces the arousal in¬dex,35 it seems appropriate to continue use of this modality in selected patients, usually as an adjunct to pharyngeal surgery or to improve the tolerance of CPAP.

The authors acknowledge that the total number of patients with preoperative and postoperative PSG data in this study is limited, preventing definitive conclusions regarding management of OSAS. An additional limitation is the fact that six patients had preoperative attended polysomnography fol¬lowed by a postoperative Edentec study, which adds a potentially confounding variable. However, the Edentec system has been validated against level I polysomnography22; furthermore, to minimize test-based differences, the ambulatory studies were restored manually by a sleep technician.

CONCLUSION

Laser-assisted uvulopalatoplasty is an effective surgical procedure for primary snoring and UARS, with success rates for snoring that are comparable to UPPP for one fourth the cost. It is appropriate to offer LAUP to patients with mild OSAS, as long as the patient is aware of the surgical success rate and the possible need for additional surgery or CPAP.

Multilevel pharyngeal surgery is the most effi-cacious procedure for OSAS evaluated in this review and is particularly appropriate for patients with se¬vere OSAS. Patients with more severe preoperative airway collapse during the modified Muller maneu¬ver had a higher rate of surgical success. Septo¬plasty with bilateral inferior turbinate resection should be reserved as an adjunct to pharyngeal surgery or to improve the tolerance of CPAP.

We recommend an incremental approach to the management of SDB in which patients with more severe disease and greater, multi-level pharyngeal collapse are given treatment with incrementally more aggres¬sive surgery that may involve higher costs and higher potential morbidity. The assessment of surgical success in the treatment of SDB should consider anatomic di¬mensions and improvement in daytime somnolence, in addition to polysomnography data.

BIBLIOGRAPHY

1. Guilleminault C, Stooks R. Clerk A. Cetel A, Maistros P. A cause of excessive daytime sleepiness: the upper airway re¬sistance syndrome. Chest 1993;104:781-7.
2. Newman JP, Clerk AA, Moore M, Utley DS, Terris DJ. Recog-nition and surgical management of the upper airway re¬sistance syndrome. Laryngoscope 1996;106(9):1089-93.
3. lkematsu T. Study of snoring, fourth report: therapy. J Jap Otorhinolarygol 1964;64:434-5.
4. Fujita S, Conway W, Zorick F, et al. Surgical correction of anatomic abnormalities in obstructive sleep apnea syn¬drome: uvulopalatopharyngoplasty. Otolaryngol Head Neck Surg 1981 89:923-34.
5. Sher AE, Schectman KB, Piccirillo JF. The efficacy of surgical modifications of the upper airway in adults with obstruc¬tive sleep apnea syndrome. Sleep 1996;19(2):156-77.
6. Riley RW, Powell NB, Guilleminault C. Obstructive sleep ap¬nea and the hyoid: a revised surgical procedure. Otolaryn¬gol Head Neck Surg 1994;111:717-21.
7. Riley RW, Powell NB, Guilleminault C. Obstructive sleep apnea syndrome: a review of 306 consecutively treated sur¬gical patients. Otolaryngol Head Neck Surg 1993; 108: 117-25.
8. Kamami Y-V. Outpatient treatment of sleep apnea syndrome with CO2 laser, LAW laser-assisted UPPP results on 46 patients. J Clin Laser Med Surg 1994;12(4):215-9.
9. Mickelson SA. Laser-assisted uvulopalatoplasty for obstruc¬tive sleep apnea. Laryngoscope 1996;106:10-3.
10. Walker RP. Grigg-Damberger MM, Gopalsami C, et al. Laser-assisted uvulopalatoplasty for snoring and obstructive sleep apnea: results in 170 patients. Laryngoscope 1996; 105:938-43.
11. Simmons FB, Guilleminault C, Silvestri R. Snoring, and some obstructive sleep apnea, can be cured by oropharyngeal surgery. Palatopharyngoplasty. Arch Otolaryngol 1984;92: 375-80.
12. Dayal VS, Phillipson EA. Nasal surgery in the management of sleep apnea. Ann Otol Rhinol Laryngol 1985;94:550-4.
13. Levin BC, Becker GD. Uvulopalatopharyngoplasty for snor¬ing: long-term results. Laryngoscope 1994;104:1150-2.
14. Krespi YP, Pearlman SJ, Keidar A. Laser-assisted uvulopalato-plasty for snoring. J Otolaryngol 1994;23(5k325-34.
15. Kamami, Y-V. Laser CO2 for snoring: preliminary results. Acta Otorhinolaryngol Berg 1990;44:451-6.
16. Sher AE, Thorpy MJ, Shprintzen 11J, Spielman AJ, Burack B, McGregor PA. Predictive value of Muller maneuver in se¬lection of patients for uvulopalatopharyngoplasty. Laryngoscope 1985;95:1483-7.
17. Johns MW. Daytime sleepiness, snoring, and obstructive sleep apnea: the Epworth Sleepiness Scale. Chest 1993;103:30-6.
18. Rechtschaffen A, Kales A, eds. A Manual of Standardized Technology: Techniques and Snoring System for Sleep Stages of Human Subjects. Los Angeles: Brain Information Service/Brain Research Institute, University of California, Los Angeles; 1968.
19. Diagnostic Classification Steering Committee, Thorpy MJ, Chairman. International Classification of Sleep Disorders: Diagnostic and Coding Manual. Rochester, MN: American Sleep Disorders Association; 1990.
20. Guilleminault C, ed. Sleeping and Waking Disorders: Indica¬tions and Techniques. Menlo Park, CA: Addison-Wesley; 1982:1-435.
21. Gould GA, Whyte KF, Rhind GB, et al. The sleep hypopnea syndrome. Am Rev Respir Dia 1988;137:895 - 8.
22. Redline S, Tosteson T, Boucher MA, Millman RP. Measure¬ment of sleep-related breathing disturbances in epidemio¬logic studies, assessment of the validity and reproducibil-ity of a portable monitoring device. Chest 1991;100(5):1281-6.
23. Fairbanks DN. Predicting the effect of nasal surgery on snor¬ing: a simple test (Jetted. Ear Nose Throat J 1991;78(1):50-2.
24. Goode RL. Diagnosis and Treatment of Turbinate Dysfunc¬tion: A Self-instructional Package. No. 77100. Washington, DC: American Academy of Otolaryngology-Head and Neck Surgery Foundation, Inc.; 1977.
25. Millman RP, Redline 5, Carlisle CC, Assaf AR, Levinson PR. Daytime hypertension in obstructive sleep apnea: preva¬lence and contributing risk factors. Chest 1991;99: 861-6.
26. Partinen M, Jamieson A, Guilleminault C. Long-term out¬come for obstructive sleep apnea syndrome patients: mor¬tality. Chest 1988;94:1200-4.
27. D'Allessandro R, Magelli C, Gamberini G, et al. Snoring every night as a risk factor for myocardial infarction: a case con¬trol study. BMJ 1990;300:1557-8.
28. Heifers EM, Franklin KA. Impairment of cerebral perfusion during obstructive sleep apneas. Presented at the Fourth World Congress on Sleep Apnea, San Francisco, CA, Octo¬ber 1994.
29. Leger D, Orvoen-Frija E, Laaban JP, et al. Motor vehicle ac¬cidents and work-related conditions of 130 sleep apnea pa¬tients. Presented at the Fourth World Congress on Sleep Apnea. San Francisco, CA, October 1994.
30. Maisel RH. Uvulopalatopharyngoplasty for obstructive sleep apnea: a community's experience. Laryngoscope 1992;102: 604-7.
31. He J, Kryger M, Sorick F, Conway W, Roth T. Mortality and apnea index in obstructive sleep apnea: experience in 385 male patients. Chest 1988;94(1):9-14.
32. Bliwise DL, Bliwise NG, Kraemer HC, Dement WC. Mea-surement error in visually scored electrophysiological scored data: respiration during sleep. J Neurosci Methods 1984;12:49-56.
33. Agnew HW, Webb WB, Williams RL. The first night effect: an EEG study of sleep. Psychophysiology 1966;2:263-6.
34. Terris DJ, Clerk AA, Norbash AM, Troell RI Characteriza¬tion of postoperative edema following laser-assisted undo¬plasty using MRI and polysomnography: implications for the outpatient treatment of obstructive sleep apnea syn¬drome. Laryngoscope 1996;106:124-8.
35. Kerr P, Millar T, Buckle P, Kryger M. The importance of nasal resistance in obstructive sleep apnea syndrome. J Oto¬laryngol 1992;21:189-95.