Practice Parameters for the Use of Laser-Assisted Uvulopalatoplasty: An Update for 2000

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Summary: Laser-assisted uvulopalatoplasty (LAUP) is an outpatient surgical procedure which is in use as a treatment for snoring. LAUP also has been used as a treatment for sleep-related breathing disorders, including obstructive sleep apnea. The Standards of Practice Committee of the American Academy of Sleep Medicine reviewed the available literature, and developed these practice parameters as a guide to the appropriate use of this surgery. Adequate controlled studies on the LAUP procedure for sleep-related breathing disorders were not found in peer-reviewed journals. This is consistent with findings in the original practice parameters on LAUP published in 1994. The following recommendations are based on the review of the literature: LAUP is not recommended for treatment of sleep-related breathing disorders. However, it does appear to be comparable to uvulopalatopharyngoplasty (UPPP) for treatment of snoring. Individuals who are candidates for LAUP as a treatment for snoring should undergo a polysomnographic or cardiorespiratory evaluation for sleep-related breathing disorders prior to LAUP and periodic postoperative evaluations for the development of same. Patients should be informed of the best available information of the risks, benefits, and complications of the procedure.

INTRODUCTION

LASER-ASSISTED UVULOPALATOPLASTY (LAUP) HAS BEEN PROMOTED AS A TREATMENT OF SNORING, AND IN SOME CASES, for sleep-related breathing disorders including obstructive sleep apnea (OSA). This surgical procedure is typically performed in an outpatient setting with local anesthesia and without postoperative hospitalization. At the present time, LAUP is in current use. In this article, we review the appropriate patient evaluation and the effectiveness, potential risks, and complications of LAUP for OSA, and provide recommendations for its use. This update generally examines evidence for LAUP in the therapy of OSA since the publication of the expert review;[1] grades the evidence available; and modifies and replaces the 1994 practice parameters.[1]

METHODS

Medline searches for articles on LAUP were conducted through September 2000. Key words for the search included LAUP, laser-assisted uvulopalatoplasty, laser-assisted uvuloplasty, laser surgery, somnoplasty, base of the tongue reduction, uvulopalatopharyngoplasty (UPPP), uvulopalatoplasty, uvuloplasty, uvulectomy, uvulotomy, uvula, and all possible combinations of the preceding terms with snoring, obstructive sleep apnea, sleep apnea syndromes, and upper airway surgery. This search led to a total of 641 articles. Thirty-two of these articles were published prior to the original American Academy of Sleep Medicine's (AASM) Practice Parameters for the Use of Laser-Assisted Uvulopalatoplasty[1] in 1994, which incorporated 17 of the 32 articles in that previous review of the literature. Articles in all languages were considered for inclusion, and were screened based on their English-language abstracts. A total of 123 articles were identified as potentially relevant based on review of the abstracts. Of these, 90 were obtained in full length and examined. Upon review of these articles, an additional 45 references were discovered by pearling (i.e., the process of selecting relevant articles referenced in the original article). These were references located in publications not typically found through Medline. The types of these publications, with the total number of publications per type (in parentheses) are listed: books (6), coursebooks (1), meeting and symposium abstracts or proceedings (8), highly specific or trade journals (30). Articles entered into the evidence tables (Tables 1 and 2) included randomized trials and nonrandomized controlled or concurrent cohort studies on the comparison with UPPP for snoring and OSA (Table 1) and peer-reviewed case series and historical cohort studies on the efficacy of LAUP for OSA (Table 2), with a minimum of five patients and a clearly defined outcome that could be used to adequately assess the therapy. In the case of the peer-reviewed case series and historical cohort studies entered in Table 2, studies were included only if the "effect size" (Table 3) or the overall effect of LAUP on the number of respiratory events during sleep (described below) could be derived from the article. Articles describing nonrandomized historical cohort studies (13), case series (45), and other studies (69) derived from the search were found useful as background articles. The Standards of Practice Committee's levels of evidence (Table 4) for treatment-related evidentiary articles, which are used to support the strength of the recommendations (Table 5) in this paper, are found in the evidence tables (Tables 1 and 2).

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On the basis of this review and noted references, the Standards of Practice Committee of the American Academy of Sleep Medicine, in conjunction with specialists and other interested parties, developed the review and recommendations included in this paper. In most cases, the conclusions are based on evidence from studies published in peer-reviewed journals that were evaluated as noted in the evidence tables (Tables 1 and 2). However, when scientific data are absent, insufficient, or inconclusive, the recommendations are based upon consensus opinion. The strength of each recommendation is based on the level of the evidence available or on consensus when evidence is lacking.

The Board of Directors of the American Academy of Sleep Medicine approved this review and these recommendations. All authors of this review, members of Standards of Practice Committee, and the Board of Directors completed detailed conflict-of-interest statements and were found to have none with regard to this subject.

These practice parameters define principles of practice that should meet the needs of most patients in most situations. These guidelines should not, however, be considered inclusive of all proper methods of care or exclusive of other methods of care reasonably directed toward obtaining the same results. The ultimate judgment regarding the propriety of any specific care must be made by the physician in light of the individual circumstances presented by the patient and the available diagnostic and treatment options as resources.

The American Academy of Sleep Medicine expects these guidelines to have a positive impact on professional behavior, patient outcomes and, possibly health care costs. These practice parameters reflect the state of knowledge at the time of development and will be reviewed, updated, and revised, as new information becomes available.

Background

LAUP is a surgical procedure that typically relies on the use of a carbon dioxide (CO_2) laser to vaporize the uvula and a part of the free edge of the soft palate during one to several sessions. Within the scope of this definition, various degrees of tissue are ablated using slightly different techniques. This procedure is different from conventional uvulopalatopharyngoplasty (UPPP), in that LAUP is performed during a comparatively brief surgical session, reduces far less palatal tissue and does not alter the tonsils or the pharyngeal pillars, uses a laser rather than a scalpel, requires no wound closure, uses local rather than general anesthesia, is conducted in an ambulatory rather than hospital setting, and requires no postoperative hospital stay.[1] LAUP is distinguished from the laser palatoplasty procedure described by Ellis[2] in which a soft palate lesion produced by a neodymium:yttrium-aluminum-garnet laser induces scarring, which stiffens the soft palate and reduces "palatal flutter," which in turn, reduces snoring.

Patient Evaluation

The selection process for candidates for this procedure ranges from patient history, questionnaire data, use of the Müller maneuver, oral and nasopharyngoscopic examination, polysomnography, and a variety of imaging studies. Although some investigators proposed decision algorithms[3] or imaging studies to localize the site of obstruction,[4,5] there is no consensus on the preoperative selection process for this procedure. However, a patient deciding on LAUP as a treatment for snoring should be properly screened for a more severe sleep-related breathing disorder such as OSA. Clinical evaluation can be unreliable; a clinical history and results of a physical examination by a physician to generate a subjective judgment as to whether a given patient did or did not have OSA yielded a correct identification in 52% of patients with OSA and a specificity of 70%.[6] Another study showed that out of 73 patients seeking LAUP treatment, 69 (95%) had OSA by polysomnography, even though 41% presented only with a complaint of snoring.[7] Additionally, the patients' subjective ratings of snoring loudness, frequency, and consequences did not correlate with any of the respiratory variables obtained by polysomnography. Thus, a sleep study, in the form of standard polysomnography or Level III recording also called a cardiorespiratory study,[8-10] is indicated to exclude the possibility of OSA in potential candidates for this procedure for snoring. A Level III recording includes at least four channels with recording of at least two respiratory effort channels or a respiratory effort channel and an airflow channel, plus oximetry and either heart rate or electrocardiogram.

Effectiveness, Risks, and Complications of LAUP for Snoring and OSA

In 1990, Kamami described the use of LAUP on 31 adult patients.[11] Following up to seven sessions a maximum of three weeks apart, snoring was completely eliminated or remained as an occasional soft snore in 24/31 (77.4%) of the patients, and a persistent non-disturbing snore in 7/31 (22.6%) of the patients. Neither infection nor significant bleeding was detected; patients reported pain similar to a simple "sore throat." The patients noted improvement in fatigue, morning headaches, and irritability; however, it is unknown whether any of the subjects had OSA, since preoperative screening polysomnography was not performed.

Although there are a number of case series subsequent to Kamami's original study, randomized placebo-controlled studies on the effectiveness of LAUP for OSA are lacking. This lack provides evidence of limited value in determining if LAUP has efficacy in OSA. However, by combining a number of the case series studies,[5,12-17] it is possible to determine an overall effect of LAUP on the number of respiratory events during sleep. The "effect size" of each study is derived from the difference between the pre- and post-LAUP number of apneas and hypopneas per hour of sleep (also called the pre- and post- apnea hypopnea index, AHI) divided by the standard deviation of the pre-LAUP AHI.[18] The effect size can be adjusted by a factor related to the number of subjects in each study.[19] The overall effect of a number of studies can be expressed as the average of the sum of individual unadjusted or adjusted effect sizes[18,19] of each study. The case series studies were selected from the total number of case series articles obtained through our literature search. The criteria used for inclusion of these articles in the calculation of effect size were studies in which the mean pre- and post-LAUP AHI across subjects as well as the pre-LAUP standard deviation were provided in the article, or could be derived from data present in the article. When the effect size analysis was performed (Table 3), the average unadjusted effect size was 0.392. The average adjusted effect

size was 0.251. Because there is no comparison with placebo or with another procedure, it is difficult to determine if this effect is likely to be meaningful. However, in general, an effect size between 0.2 and 0.5 (as is the average in the LAUP studies) is considered to be in the small range.[18] By comparison, an effect size between 0.5 and 0.8 is considered to be medium and greater than 0.8 is considered to be large.

The reader should be aware of the following in interpreting information on LAUP. It is not clear if the general interpretation of effect size can be applied to the specific case of LAUP. The reduction in AHI may not be clinically significant since there are few outcome measures such as sleepiness and systematic quality of life reported in the literature. Although the overall effect is a small improvement, individual patients may show no reduction or an increase in AHI.[20] Apart from the near-term post-operative effects of LAUP on AHI, the long-term efficacy of LAUP on OSA is undefined. Interpretation of the effect of LAUP is based on studies that have described different surgical procedures ranging from excising comparable amounts of tissue as those removed with UPPP,[21] to varied and lesser excisions.[22,23]

As illustrated in Table 2, there are six Level III studies, representing nonrandomized controlled or concurrent cohort studies, [3,21,24-27] comparing LAUP vs. UPPP (either with or without tonsillectomy).[3,21,24-27] One study evaluated OSA,[24] one study examined snoring and OSA[3] and one study examined snoring and upper airway size.[26] Two of the three studies showed a decrease in AHI which because of sample size could not be compared for degree of efficacy to UPPP;[3,24] the remaining study showed worsened postoperative upper airway anatomic characteristics by oral and nasopharyngoscopic examination for LAUP compared to UPPP patients.[25] Four studies reported subjective postoperative improvement in snoring levels with LAUP and no significant differences in levels of improvement between LAUP vs. UPPP.[3,21,26-27] However, interpretation of the results of all of the above studies is difficult given the relative lack of detailed statistical analyses of the data. As mentioned above, comparisons between studies are further limited by lack of standardization of the procedure.

Lastly, the long-term effectiveness of LAUP on treatment of snoring has not been convincingly established. Two separate studies found snoring improvement of 89.6% and 90%, in patients assessed between one and eight years and at five years following LAUP.[28,29] Less satisfactory results were found in a study that showed snoring improvement was reduced to 62.2% beyond two years.[14] Another study found that 22% of patients had recurrence of snoring between 18 and 24 months following LAUP, with an overall success rate of 55% at 24 months,[30] and a separate study found snoring improvement in 43% of patients, with 21% showing no improvement and 36% showed significant deterioration on sleep studies performed 3 to 24 (mean=7) months postoperatively.[31] Following an average post-LAUP duration of four years, another study found that 51.6% of patients reported that their snoring was eliminated.[13] As mentioned , the long-term efficacy on LAUP on OSA is not defined but should be considered problematic in view of the inconsistent findings on the long-term efficacy of LAUP on snoring.

There are data to suggest that the pain levels associated with LAUP may be comparable to those of UPPP. One study showed no difference between the average pain scores for the first (typically the most painful) LAUP stage and UPPP.[26] However, the patients treated with UPPP remained in the hospital overnight and received parenteral analgesia. Another study showed similar maximum pain peaks and intensity for LAUP vs. UPPP, with comparable mean durations of the pain period of 13.76 and 11.80 days, respectively.[3] Similar results were reported in a separate study, which found comparable mean durations of the pain period for LAUP (13.8 days) vs. UPPP (14.3 days).[32]

Besides pain, the most commonly reported side effects from LAUP appear to be transient velopharyngeal insufficiency, minor bleeding, local infection, globus sensation, and minor dysphonia and dysphagia.[33,34] Based on the literature review, the most common side effects with their reported frequency of occurrence are listed in Table 6. In 27% of LAUP patients, either persistent dysphagia[35] or mild or moderate scar fibrosis[24] have been observed. Postoperative swelling may compromise an already marginal upper airway; use of narcotics or sedatives may further complicate this problem. Alcohol should be avoided because of its adverse effects on upper airway muscle tone and closing pressures in snorers.[36] The smoke plume from lasers can create a biological and chemical hazard for the patient and surgical team; however, an efficient smoke evacuator used during LAUP can obviate this hazard.[37]

There is also evidence to indicate that LAUP may result in a diminished velopharyngeal air space and decreased distensibility.[25] This study suggests that these structural modifications of the upper airway may decrease airway resistance, resulting in further narrowing during inspiration and collapse of the upper airway at the level of the tongue base, and consequent OSA. These results, from an anatomical perspective, indicate that LAUP may have a worse outcome than UPPP. A separate study examining LAUP patients between 48 and 72 hours after LAUP found worsening of the AHI, with a significant decrement in the cross-sectional area of the airway by videoendoscopy.[20] A study examining histopathologic changes of the soft palate after LAUP found extensive thermal-induced changes including diffuse fibrosis, oral epithelia ulceration, and a patchy inflammatory reaction, which the authors speculate may be responsible for worsening of OSA.[38]

The selection process for candidates for LAUP or the anatomic, histopathologic, and physiologic effects of this procedure have not been well characterized, and there is a lack of understanding of its consequences on pathologic respiration and its long-term effectiveness. In general, since insufficient data exists on the effectiveness and risks of LAUP, patients who elect to undergo this procedure as a treatment for snoring should have appropriate preoperative evaluation including screening for OSA, and should have close postoperative follow-up to monitor the patient for possible complications of this procedure.

CONCLUSIONS AND RECOMMENDATIONS

The following recommendations of the Standards of Practice Committee and the Board of Directors of the American Academy of Sleep Medicine are similar to those published in its last report in 1994, since adequate controlled studies on the LAUP procedure were not found in peer-reviewed journals. The classification of evidence was adapted from the suggestions of Sackett[39] (Table 4). Recommendations are given as standards, guidelines, and options, as defined in Table 5.

1. **LAUP is not recommended for the treatment of the sleep-related breathing disorders including obstructive sleep apnea. (Guideline)**

   There is insufficient evidence to recommend LAUP for the treatment of the obstructive sleep apnea syndrome. The Level V, Grade C evidence from seven articles[5,12-17] indicates that LAUP provides a small overall decrease in AHI in a group of patients, that preoperative prediction strategies for selecting patients who respond have not been developed, that some patients may have an increase in AHI, and that there is insufficient information on other outcome measures or long-term efficacy. Therefore, we do not recommend LAUP for the treatment of obstructive sleep apnea. This recommendation is similar to a recommendation of the previous practice parameter paper.[1]

2. **LAUP is not recommended as a substitute for UPPP in the treatment of sleep-related breathing disorders including obstructive sleep apnea. (Guideline)**

   There are three studies with Level III, Grade C evidence[3,24,25] on comparison including measurement of AHI or airway size. When considered in conjunction with the small effect size of LAUP on AHI, these studies provide insufficient evidence to indicate that LAUP is an acceptable substitute for UPPP with respect to either effectiveness or side effect profiles as a treatment for OSA. This is a new recommendation.

3. **LAUP appears comparable to UPPP in relieving subjective snoring. (Guideline)**

   There are 4 Level III, Grade C studies that compare LAUP to UPPP for snoring. These studies suggest that LAUP can reduce snoring measured by subjective criteria to a similar degree as UPPP. This is a new recommendation.

4. **Surgical candidates for LAUP as a treatment for snoring should undergo a preoperative clinical evaluation and a polysomnographic or a cardiorespiratory study[8-10] to determine if the candidate has a sleep-disordered breathing disorder including obstructive sleep apnea. (Standard)**

   Since snoring is a primary diagnostic symptom, patients who undergo LAUP should be informed of the need for periodic evaluation for subsequent development of obstructive sleep apnea even if the procedure reduces or eliminates snoring. (Standard)

   These recommendations are based on information regarding the natural course of OSA. Snoring may predate onset of OSA, as well as other symptoms of OSA such as excessive daytime sleepiness.[40] Although snoring is neither necessary nor sufficient for the diagnosis of a sleep-related breathing disorder, it is frequently an associated symptom. It is estimated that the occurrence of obstructive sleep apnea ranges from 25% to as high as 95% in snorers.[8,9] In one study reviewing patients seeking LAUP treatment specifically for snoring, 95% had OSA by polysomnography.[5] The presence of other risk factors for sleep apnea such as obesity and age, as well as other associated symptoms such as daytime sleepiness and witnessed breathing pauses, increase the risk for concomitant sleep apnea. Given the life-threatening conditions (e.g., myocardial infarction, cardiac failure, stroke) associated with sleep-related breathing disorders and the increased risk for motor-vehicle or industrial accidents secondary to the daytime sleepiness related to sleep-disordered breathing, it is prudent to test for these disorders. Patients who elect to undergo LAUP for the treatment of snoring may also be at risk of incurring a delay in the diagnosis of OSA because snoring may be reduced or eliminated by LAUP. Thus, after LAUP for treatment of snoring, the patient should be notified regarding the possibility of developing OSA, and should be monitored for the occurrence of this disorder. These recommendations are similar to recommendations of the previous practice parameter paper.[1]

5. **The need for medications that affect respiration during the perioperative period should be assessed during the preoperative clinical evaluation (Standard).**

   This recommendation is based on consensus of the SPC. the perioperative use of narcotics may pose risks for patients who have undergone LAUP operations; therefore, the need for these medications should be carefully assessed during the preoperative clinical evaluation. Careful clinical judgment should be used when prescribing other pain medications, sedatives, sleeping pills and alcohol during the perioperative period. The rationale is that these medications may blunt respiratory drive. This is especially important since postoperative swelling may reduce the caliber of an already narrowed airway. Alternatives, such as oral or topical non-narcotic pain medications during the perioperative periods, should be used whenever possible, and hypnotics and alcohol should be avoided because of their deleterious effects on upper airway tone. This recommendation is similar to a recommendation of the previous practice parameter paper.[1]

6. **Patients should be informed of the risks and complications of LAUP. (Standard)**

   There are studies specifically evaluating the risks and complications of LAUP (Table 6). Any patient electing to undergo LAUP for treatment of snoring should be informed of the potential risks and complications of this procedure. This recommendation is based on the documented risks of LAUP and SPC consensus and is similar to a recommendation of the previous practice parameter paper.[1]

RECOMMENDATIONS FOR FUTURE RESEARCH

Investigations to identify the best treatment for snoring or OSA should include well-powered, multicenter clinical trials using randomized study designs with an appropriate endpoint or outcome. The use of objective measures for evaluating outcomes and sham or sub-therapeutic controls is encouraged. Future studies should provide LAUP definitions, long-term effectiveness data, cost-benefit analyses, direct comparison between different treatments, and the impact of treatment on quality of life.

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Table 1. LAUP Controlled Trials

LAUP, laser-assisted uvulopalatoplasty; DVT, deep venous thrombosis; NPO, nocturnal pulse oximetry; NRan, nonrandomized; Ran, randomized; *, significant difference; UPPP, uvulopalatopharyngoplasty; VPI, velopharyngeal insufficiency; PSG, polysomnography; AHI, apnea/hypopnea index; RDI, respiratory disturbance index which is interchangeable with AHI

Reference/ Evidence Level	Study Design	Procedure; Number of Sessions; Protocol	Diagnostic Criteria	Sample Size / Age / Sex of Subjects	Outcome Measures	Adverse Effects	Conclusions	Comments
Remacle (3) Level III -C	NRan concurrent cohort study	LAUP vs. UPPP; decisional algorithm: LAUP or UPPP if AHI <40 or if AHI >40 and fails CPAP; UPPP if hypertrophic palatine tonsils and long or thickened velum; postop PSG after 6 mo	Snoring: patient history OSA: screening NPO; if positive, PSG	N=89 / 23-77 y / 70M, 19F; 78 completed (63 had surgery for habitual snoring, 15 for OSA)	Questionnaires NPO: normal, <90% in <1% of night and <5% of desat of mean O_2 sat; improved, 1 of 2 criteria met; failure, no change PSG: normal, AHI <10; improved, AHI decreased by at least 1 AHI stage (≥10 and <20, ≥20 and <40, ≥40); failure, no change in AHI stage	LAUP: 6% minor dysphonia x 1y; 1 case severe dysphagia; 1 case minor bleeding UPPP: 20% temp nasal regurgitation; 20% minor dysphonia x 1 y	LAUP vs. UPPP: no sig difference in pain level or duration by questionnaires, no sig difference in satisfaction on 0-10 scale (7.68 vs. 8.60, resp) NPO: postop 8 normal, 5 improved, 1 failure, 1 refused PSG: postop 4 normal, 2 improved, 2 failures, 7 refused	Significant dropout rate for return PSG (7/15 refused follow-up PSG)
Walker (24) Level III -C	NRan	LAUP vs. UPPP; 1 or more LAUP procedures; UPPP included tonsillectomy (32/41) and nasal surgery (25/41); postop PSG after 3 mo	OSA: PSG with RDI >5	N=167, 79 completed (38 LAUP / 31M, 7F / mean = 53.6 y; 41 UPPP / 40M, 1F / mean = 45.7 y)	PSG: >50% RDI reduction in postop PSG vs. preop PSG	LAUP: 2/38 bleeding; 2/38 oral candidiasis; 1/38 temp VPI UPPP: 2/41 bleeding; 3/41 temp VPI; 1/41 lower extremity DVT	Postop RDI >50% reduction: 18/38 LAUP; 21/41 UPPP Postop RDI reduction: 30.3 to 22.2 LAUP*; 52.1 to 25.5 UPPP* Postop min O_2 change: 83.3 to 81.6%; LAUP; 72.8 to 80.9% UPPP*	
Finkelstein (25) Level III -C	NRan	First 100/174 consecutive patients had UPPP, remaining 74/174 had LAUP (first 34/74 had incision comparable to UPPP with	Snoring: negative for OSA by PSG OSA defined as PSG with RDI >5	N= 174 / 22-71 y / 157M, 17F (16 with heavy snoring only)	Intraoral photographs of soft palate; peroral and nasopharyn-goscopic examination	None reported	LAUP: circumferential scarring, resulting in decreased velopharyngeal air space and decreased	

Reference/ Evidence Level	Study Design	Procedure; Number of Sessions; Protocol	Diagnostic Criteria	Sample Size / Age / Sex of Subjects	Outcome Measures	Adverse Effects	Conclusions	Comments
		tonsillotomy; remaining 40/74 uvula reduced); follow-up intraoral photography, peroral and nasopharyngoscopic examination up to 12 weeks postop					distensibility UPPP: enlarged oropharynx and increased velopharyngeal air space	
Maw (26) Level III -C	NRan	LAUP vs. tonsillectomy and UPPP; eligible if Müller maneuver showed 75% and ≤50% obstruction at level of soft palate and tongue base, resp; ≥50% obstruction due to tonsillar hypertrophy = UPPP, <50% = LAUP (up to 4 stages); follow-up 4 wk postop	Snoring: history, questionnaire, PSG with AHI ≤20	N=136; 129 completed (80 LAUP / mean = 50 y / 88% M; 29 UPPP / mean = 41 y / 93% M)	Questionnaire	LAUP: pain level equivalent to UPPP; 3/80 delayed postop bleeding UPPP: 1/29 delayed postop bleeding	LAUP vs. UPPP: no sig differences for final snoring scores, pain, or complication rates. Selection by Müller maneuver allowed ≥50% reduction in final snoring scores in 97% of patients.	
Wennmo (27) Level III -C	NRan	LAUP vs. UPPP vs. UPPP with tonsillectomy; patients in the first 2 groups were selected for small tonsils; follow-up from 3 mo to 2 y	Snoring: questionnaire	N=30 (10 LAUP / mean = 47 y / M:F ratio = 9:1; 10 UPPP / mean = 45.3 y / M:F ratio = 10:0; 10 UPPP with tonsillectomy / mean = 44.5 y / M:F ratio = 9:1)	Questionnaire	UPPP with tonsillectomy: 1 with bleeding; 2 with minor oropharyngeal discomfort	Snoring: subjective improvement in all patients except for one in the UPPP with tonsillectomy group	Small sample size; selection bias

Reference/ Evidence Level	Study Design	Procedure; Number of Sessions; Protocol	Diagnostic Criteria	Sample Size / Age / Sex of Subjects	Outcome Measures	Adverse Effects	Conclusions	Comments
Carenfelt (21) Level III -C	NRan	LAUP vs. UPPP; randomized 33 patients for LAUP and 37 patients for UPPP, then added an additional 30 consecutive patients for LAUP; follow-up 3-4 mo postop	Snoring: snoring at level of velopharynx, distance between faucial tonsils >25 mm, no simultaneous nasal surgeries performed, PSG <10 obstructive apneas >10 sec	N=100 (63 LAUP / 24-70 y / 18% F; 37 UPPP / 30-74 y / 14% F); returned for follow-up: 60 LAUP; 36 UPPP	Questionnaire	LAUP: 1 patient with incomplete surgery due to strong vomiting reflexes; 16 patients with slight or moderate scar fibrosis; 2 patients with scar fibrosis with narrowed nasophayngeal aperture and nasal obstruction, worsened scarring after reoperation with UPPP UPPP: 5 patients with slight or moderate scar fibrosis	Total or near-total snoring elimination: 51/60 LAUP; 32/36 UPPP Without complaints from family: 56/60 LAUP; 33/36 UPPP No habitual daytime sleep attacks: 15/21 LAUP; 10/13 UPPP	Considered a nonrandom-ized study due to selection bias and partial randomiza-tion of LAUP group

Table 2. LAUP OSA Case Series and Cohort Studies

LAUP, laser-assisted uvulopalatoplasty; LSAT, lowest oxygen saturation; *, significant difference; UPPP, uvulopalatopharyngoplasty; MPS, multilevel pharyngeal surgery; STR, septoplasty with turbinate reduction; VPI, velopharyngeal insufficiency; PSG, polysomnography; AHI, apnea/hypopnea index; RDI, respiratory disturbance index which is interchangeable with AHI; UARS, upper airway resistance syndrome; MSLT, multiple sleep latency test; HA, headache

Reference/ Evidence Level	Study Design	Procedure; Number of Sessions; Protocol	Diagnostic Criteria	Sample Size / Age / Sex of Subjects	Outcome Measures	Adverse Effects	Conclusions	Comments
Ryan (12) Level V	Case Series	LAUP; one-stage resection; postop PSG after 3 mo	OSA by PSG	N=44 / mean = 49 y / 37M, 7F	PSG: good response, AHI ≤10; partial response, AHI ≤50% of pre-LAUP value; poor response, AHI >50% of pre-LAUP value; worse, AHI >100% of pre-LAUP value Videoendo-scopy Questionnaires	excessive mouth dryness, throat pain or discomfort	PSG: postop 12 good response, 4 partial response, 15 poor response, 13 worse Videoendo-scopy: increased cross-sectional and anteroposterior diameter* Questionnaires: improved quality of life*, sleepiness*, and snoring index	
Walker (13) Level V	Case Series	LAUP; postop PSG after 3 mo, long-term questionnaire data	OSA by PSG	N=182, 131 completed treatment, 40 with complete postop PSG data and without interim surgery or PSG <6 wks postop, 31 with long-term data / 35–75 y / 30M, 10F	PSG Questionnaire	None reported	PSG: AHI improved* from mean of 25.0 to 15.3, REM% increased* from mean of 13.3 to 17.6 Questionniare: presenting complaints improved in 74.9% after mean followup of 4.04 y in 31 subjects	

Reference/ Evidence Level	Study Design	Procedure; Number of Sessions; Protocol	Diagnostic Criteria	Sample Size / Age / Sex of Subjects	Outcome Measures	Adverse Effects	Conclusions	Comments
Mickelson (14) Level V	Case Series	LAUP; PSG 6-12 wks postop, questionnaire data from patient and bedpartner before LAUP, 6-12 wks postop, and >2 y	PSG: OSA defined as RDI >10	N= 59, 36 completed postop PSG; MSLT pre- and postop in 7 patients / mean = 52.3 y / 29M, 7F	PSG MSLT Questionnaires	1 patient with several drops of bleeding controlled with cautery; 1 patient taking ibuprofen for pain who bled about 30 ml on postop day 4 that ceased spontaneously	PSG: AHI decreased* from mean of 28.1 to 7.9, min O2 saturation increased from mean of 80.6% to 84.0% MSLT: mean sleep latency improved* Questionnaire: improved* snoring, morning fatigue, morning HA, daytime somnolence, daytime psychometric measures	

Reference/ Evidence Level	Study Design	Procedure; Number of Sessions; Protocol	Diagnostic Criteria	Sample Size / Age / Sex of Subjects	Outcome Measures	Adverse Effects	Conclusions	Comments
Walker (15) Level V	Case Series	LAUP; 3-6 treatments; postop PSG ≥ 3 mos after LAUP	PSG: mild OSA (AHI >5 and <20), moderate OSA (AHI ≥20 and ≤39), severe OSA (AHI ≥40)	N= 38 / 39-75 y / 31M, 7F	PSG: surgical response rate defined as ≥50% AHI reduction in postop PSG vs. preop PSG and a postop AHI<20	2 with bleeding, 2 with oral candidiasis, 1 with temporary VPI	PSG: mild OSA AHI decreased from 10.5 to 10.4 (surgical response rate of 46.7%) and LSAT decreased from 87.2% to 86.8%; moderate OSA AHI decreased from 29.0 to 21.1 (surgical response rate of 41.7%) and LSAT decreased from 81.3% to 80.4%; severe OSA AHI decreased from 59.7 to 39.6 (surgical response rate of 45.5%) and LSAT increased from 80.3% to 81.1%	

Reference/ Evidence Level	Study Design	Procedure; Number of Sessions; Protocol	Diagnostic Criteria	Sample Size / Age / Sex of Subjects	Outcome Measures	Adverse Effects	Conclusions	Comments
Utley (16) Level V	Retro-spective Cohort	LAUP; mild OSA (AHI >5 and <20) patients encouraged to undergo LAUP or UPPP, if they had significant findings on the modified Muller maneuver, they were encouraged to have MPS; those patients with moderate OSA (AHI ≥20 and <40) or severe OSA (AHI ≥40) were offered MPS; those with significant nasal obstruction unresponsive to medication were offered STR; postop PSG min of 4 mos after LAUP	Snoring UARS OSA: surgical response rate defined as >50% drop in AI or AHI, with a postop AI <10 or postop AHI <20	N= 229, 95 candidates for surgery, 56 for LAUP (12 with postop PSG) and 32 for MPS (14 with postop PSG) and 6 for STR/ LAUP mean = 45.3 y, MPS mean = 46.1 y, STR mean = 48.8 y/ LAUP 50M, 6F, MPS 30M 2F, STR 5M 1F	PSG Modified Muller maneuver Questionnaires	LAUP: 1 with vasovagal episode during LAUP, 1 with bleeding requiring electrocautery MPS: all with transient paresthesia of mandibular incisors, 5 with gingivolabial sulcus incision dehiscences, 2 extruded screws and mandibular bony segments, 1 with moderate ecchymosis and edema of the neck and face skin without airway compromise, 1 with gingivolabial sulcus wound infection STR: none reported	PSG: LAUP OSA surgical response rate of 41.7% (5/12), MPS response rate of 85.7% (12/14), STR 16.7% (1/6) Modified Muller maneuver: palatal collapse decreased* post LAUP; collapse at all 3 levels decreased* post MPS Epworth: improved post LAUP*, post MPS*, and post STR Snoring: complete cure in 41.8% post LAUP, 50% post MPS, and 16.7% post STR	pre- and postop PSG were different mixtures of attended and unattended studies; some patients in LAUP group had UARS

Reference/ Evidence Level	Study Design	Procedure; Number of Sessions; Protocol	Diagnostic Criteria	Sample Size / Age / Sex of Subjects	Outcome Measures	Adverse Effects	Conclusions	Comments
Skatvedt (5) Level V	Case Series	LAUP; postop PSG 3-16 mos after LAUP	OSA by PSG	N= 16 / 26-63 y / 15M, 1F	PSG Continuous pharyngeal and esophageal pressure measures with a nasal tube containing 6 pressure sensors Questionnaire	None reported	PSG: improved* duration of respiratory events, AHI, incidence of sleep with snoring, microarousal index, and mean duration of NREM sleep related to total NREM time associated with O2 sats <80% Continuous pressure measures: velopharyngeal obstructive segments in 90% preop (9% postop), and in hypopneas, 92% preop(85% postop Questionnaire: reduced* incidence and loudness of snoring, apneas, morning fatigue, excessive daytime sleepiness, and morning HA	

Reference/ Evidence Level	Study Design	Procedure; Number of Sessions; Protocol	Diagnostic Criteria	Sample Size / Age / Sex of Subjects	Outcome Measures	Adverse Effects	Conclusions	Comments
Walker (17) Level V	Case Series	LAUP; 1-5 treatments for snoring, 1-7 treatments for OSA; postop PSG ≥ 3 mos after LAUP	PSG: OSA defined as RDI >5	N= 170, 105 with snoring, 65 with OSA (33 with postop PSG) / mean = 51.9 y / 28M, 5F	PSG: OSA surgical success defined as postop RDI ≤10 Questionnaires	None reported	Snoring: 60% with complete elimination of snoring, 29% with partial improvement, 10% without improvement OSA: 48% with surgical success; 21% with worse results, 15% without significant change	

Table 3. Effect Size of LAUP OSAS Case Series and Cohort Studies

Reference	Number of subjects	AHI Mean (SD)		Duration*	Effect Size**	Comments
		Pre-LAUP	Post-LAUP			
Ryan (12)	44	29 (17)	19 (15)	min 3 mos	0.588	Calculated SD from SE
Walker (13)	40	25 (17.7)	15.3 (18.3)	48-896 days	0.548	Calculated SD from SE
Mickelson (14)	36	28.1 (17.3)	17.9 (13.5)	6-12 weeks	0.590	
Walker (15)	38	30.6 (22.6)	22.2 (26.8)	min 3 mos	0.369	
Utley (16)	12	8.9 (6.1)	10.3 (8.1)	min 4 mos	-0.230	
Skatvedt (5)	16	18.6 (23.4)	6.4 (10.2)	3-16 mos	0.522	
Walker (17)	33	29.4 (21.2)	21.8 (24.7)	min 3 mos	0.358	
Summary	219	NA	NA	NA	0.392	Unadjusted average of effect sizes***
Summary	219	NA	NA	NA	0.251	Adjusted average of effect sizes****

SD - Standard Deviation of the mean

SE - Standard error of the mean

SE = SD/(square root of the number of subjects)

* Time from last LAUP treatment to post-LAUP PSG

** Effect size = (Pre-LAUP AHI mean - Post-LAUP AHI mean) / Pre-LAUP AHI standard deviation

***unadjusted average is the sum of the individual effects sizes/the number of studies (7 in this case)

****adjusted average is $1/SE^2$ times [(Pre-LAUP AHI mean - Post-LAUP AHI mean)/ Pre-LAUP AHI standard deviation] for each study and summing the results. This sum is divided by the sum of the $1/SE^2$ for each of the 7 studies where SE is the standard error of the pre-LAUP mean

NA - Not applicable

Table 4. AASM Classification of Evidence

Recommendation Grades	Evidence Levels	Study Design
A	I	Randomized well-designed trials with low-alpha & low-beta errors*
B	II	Randomized trials with high-beta errors*
C	III	Nonrandomized controlled or concurrent cohort studies
C	IV	Nonrandomized historical cohort studies
C	V	Case series

ADAPTED FROM SACKETT [39]

*Alpha error refers to the probability (generally set at 95% or greater) that a significant result (e.g., $p<0.05$) is the correct conclusion of the study or studies. Beta error refers to the probability (generally set at 80% or 90% or greater) that a nonsignificant result (e.g., $p>0.05$) is the correct conclusion of the study or studies. The estimation of beta error is generally the result of a power analysis. The power analysis includes a sample size analysis which projects the size of the study population necessary to ensure that significant differences will be observed if actually present.

Table 5. AASM Levels of Recommendations

Term	Definition
Standard	This is a generally accepted patient-care strategy, which reflects a high degree of clinical certainty. The term standard generally implies the use of Level I Evidence, which directly addresses the clinical issue, or overwhelming Level II Evidence.
Guideline	This is a patient-care strategy, which reflects a moderate degree of clinical certainty. The term guideline implies the use of Level II Evidence or a consensus of Level III Evidence
Option	This is a patient-care strategy, which reflects uncertain clinical use. The term option implies either inconclusive or conflicting evidence or conflicting expert opinion.

ADAPTED FROM EDDY [41]

Table 6. LAUP Adverse Effects

Adverse Effects*	Frequency (%)	References
Choking at meals	81	42
Dysphagia		
Temporary	31	43
Persistent	5 - 53	44,45
Severe	1	3
Poor appetite	21	43
Dry throat (Persistent)	16 - 42	44,46,47
Problems drinking (Persistent)	16	44
Globus sensation (Persistent)	10 - 25	42,45,47,48
Increased gag reflex	10	48
Differences in swallowing (Persistent)	6	47
Dysphonia (Mild)	6	3
Vasovagal episode	1.8	16
Voice change (Temporary)	1.7 - 17.2	46,49
Nasal regurgitation		
Temporary	1.7 - 10.3	43,46,49
Persistent	1 - 20	44,45,47,50
Vomiting	1.5	21
Bleeding		
Non-severe, immediate or delayed postoperative, includes hemoptysis	1 - 8	3,15,24,26,33,43,49,51,52,53,54,55
Requiring medical attention	0.4 – 1.8	16,23,33,54
Velopharyngeal insufficiency (Temporary)	0.5 - 3	24,33,44,51,56
Loss of taste		
Temporary	0.3	33
Persistent	5	48
Scar fibrosis	0.2 – 30 (100**)	21,38,56
Mild-Moderate	25	21
Severe	3	21
Infection		
Bacterial	0.13	33
Oral candidiasis	0.4 – 5.3	24,33,52
Septicemia - fatal	.03 (1/2900)	57
Indeterminate type	0.4 - 2	23,51

* Other than temporary postoperative pain not exceeding 3 weeks in duration; Temporary defined as equal to or less than one month duration; Persistent = greater than one month duration; Reported nonspecific or vague symptomatology are not included.
** Histopathologic study