REVIEW

Laser-Assisted Uvulopalatoplasty for Obstructive Sleep Apnea: A Systematic Review and Meta-Analysis

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Study Objectives: Laser-assisted uvulopalatoplasty (LAUP) has been used as treatment for obstructive sleep apnea (OSA). The objective of this study was to perform a systematic review and meta-analysis for LAUP alone as treatment for OSA in adults.

Methods: Three authors searched five databases (including PubMed/MEDLINE) from inception through October 30, 2016 for peer-reviewed studies, with any design/language. A study quality assessment tool was used. The PRISMA statement was followed. A meta-analysis was performed.

Results: Twenty-three adult studies (717 patients) reported outcomes (age: 50 ± 9 years, body mass index: 29 ± 4 kg/m^2). The pre- and post-LAUP means (*M*) ± standard deviations (*SD*s) for apnea–hypopnea index (AHI) were 28 ± 13 and 19 ± 12 events/h (32% reduction). Random effects modeling for 519 patients demonstrated an AHI mean difference (MD) of −6.56 [95% CI −10.14, −2.97] events/h. Individual patient data analyses demonstrate a 23% success rate (≥50% reduction in AHI and <20 events/h) and an 8% cure rate. Additionally, 44% of patients had worsening of their AHI after LAUP. Lowest oxygen saturation (LSAT) improved from a *M* ± *SD* of 80 ± 8% to 82 ± 7%. A limitation is that most studies were case series studies and only two were randomized controlled trials.

Conclusions: In this meta-analysis, LAUP reduced AHI by 32% among all patients; while the LSAT only changed minimally. Individual data demonstrated a success rate of 23%, cure rate of 8%, and worsening of the AHI among 44% of patients. We recommend that LAUP be performed with caution or not performed at all given the unfavorable results of currently published studies.

Keywords: laser-assisted uvulopalatoplasty, sleep apnea syndromes, systematic review, meta-analysis.

Statement of Significance

There are three important points. First, laser-assisted uvulopalatoplasty (LAUP) can potentially worsen obstructive sleep apnea (OSA; 44% of patients with individual data). Second, primary snoring patients who no longer snore after LAUP should be tested for OSA post-operatively if they develop signs and symptoms of OSA. Third, given that reflexogenic dilation of the pharyngeal airway is at least partially mediated by pharyngeal mucosa afferent nerve fibers, it is possible that by destroying the surface of the soft palate with a laser, that there may be blunting of the reflexogenic dilation of the pharyngeal airway. Therefore, LAUP should be performed with caution or not performed at all. Proper patient counseling is essential.

INTRODUCTION

Laser-assisted uvulopalatoplasty (LAUP) has been described as treatment for snoring and obstructive sleep apnea (OSA). In 1990, Dr Kamami described the preliminary results for the use of a carbon dioxide (CO_2) laser to ablate the soft palate of 31 patients as treatment for snoring.[1] Originally, LAUP was performed as a clinic procedure, with the patient placed in the seated position, under local anesthetic, with CO_2 laser vaporization of the "wide lateral pharyngeal walls and low arched soft palate, on both sides of the uvula, sparing the uvula."[1] In 1994, Dr Kamami published on the use of LAUP for OSA patients, with 40 of 46 patients being classified as responders.[2]

Over the years, there have been several studies reporting outcomes for LAUP as treatment for snoring and OSA. In 1994, the American Sleep Disorders Association published practice parameters against the use of LAUP as treatment for snoring and OSA.[3] A meta-analysis of LAUP studies published through 1999 was performed by Verse and Pirsig, with the findings that "short-term results are promising" and the conclusion of "LAUP and its related procedures should not be recommended for the treatment of any severity of OSA."[4] In 2000, the American Academy of Sleep Medicine's Standards of Practice Committee published updated parameters for the use of LAUP (AASM's Practice Parameters for LAUP) and stated that "LAUP is not recommended for the treatment of sleep-disordered breathing."[5]

Since then, however, several articles have reported outcomes for LAUP as treatment for snoring and OSA and we sought to review the literature and perform an updated meta-analysis. The objectives for this systematic review (using the PICOS acronym) are as follows: Adult *patients (P)* (≥18 years) who have OSA and are being treated with the LAUP as a sole *intervention (I)* and to *compare (C)* pre- and post-LAUP quantitative *outcomes (O)* (ie, apnea–hypopnea index [AHI], lowest oxygen saturation [LSAT], and sleepiness data [such as the Epworth Sleepiness Scale[6] {ESS}]) identified by searching the international literature for published *studies (S)* of any design.

METHODS

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement and checklist were followed as much as possible during this review.[7]

Protocol

The Tripler Army Medical Center Department of Clinical Investigation approved the protocol for this meta-analysis (Protocol TAMC 16N14).

Eligibility Criteria

Inclusion criteria for this review: (1) *Patients:* adults who have OSA (OSA was defined as an AHI of 5 or greater on

polysomnography using either an in-lab study or a home sleep test; overnight oximetry and clinical diagnoses were not acceptable for inclusion); (2) *Intervention:* LAUP (with or without tonsillotomy/tonsillectomy/pharyngoplasty) as the sole procedure; (3) *Comparison:* quantitative data pre- and post-LAUP; (4) *Outcomes:* sleep study data and/or sleepiness data; and (5) *Study design:* published, peer-reviewed studies with no language or publication year limitation. Exclusion criteria: (1) studies with other procedures performed in addition to LAUP (ie, nasal surgery, tongue surgery, skeletal surgery), and no substratification was made for LAUP as a sole procedure; (2) studies with qualitative outcomes alone; and (3) patients who have central sleep apnea only.

Information Sources

Databases searched included PubMed/MEDLINE, Embase, Cumulative Index to Nursing and Allied Health (CINAHL), Google Scholar, and The Cochrane Library. Each database was searched from inception through October 30, 2016.

Search

An example of a search strategy for PubMed/MEDLINE is: ((laser AND uvul*) OR (LAUP) OR (LAVP) OR (laser AND (apnea OR apnoea OR sleep))).

Study Selection

Study titles and abstracts were screened and eligible studies identified as those with sleep study or sleepiness data. The final studies included in the systematic review and meta-analysis had quantitative data available pre- and post-operatively.

Data Collection Process

Three authors (MC, NBN, and EL) searched the international literature independently, identified the potentially relevant articles, and used the inclusion and exclusion process to determine which studies met criteria. Differences in opinion were resolved via consensus and the plan was for the first author (MC) to make the final decision if there was a lack of consensus.

Risk of Bias

The Cochrane Collaboration's recommendation for assessment of bias was followed for evaluating the quantitative variables (at least 10 studies need to report outcomes for a specific variable in order to assess the funnel plot).

Summary Measures

The principle summary measures in this meta-analysis are the mean differences (MDs) and standardized mean differences (SMDs) with the 95% confidence intervals [95% CIs].

Synthesis of Results

The Cochrane Q statistic (Q statistic) was used for evaluating heterogeneity and a p-value ≤ .10 was used as the cutoff for statistical significance.[8] The inconsistency (I^2 statistic) was calculated and values were defined as low inconsistency = 25%, moderate inconsistency = 50%, and high inconsistency = 75%.[9] When heterogeneity was present, a sensitivity analysis was performed to determine which study or studies were the source(s). With regard to the respiratory disturbance index (RDI), the plan was to combine data with AHI and also to perform a separate subanalysis for RDI using individual patient data. If a study provided figures with data that were not presented anywhere else in the manuscript, then we used the figures to estimate the values for the data (ie, means and standard deviations [*SD*s]). If a study did not report the *SD*, then the meta-analysis total combined value was utilized as an estimate of the *SD*. If a study had a *SD* of zero, then the study was excluded from REVMAN random effects modeling. Data for outcomes of individual studies were combined in order to provide one pre- and post-operative value. If data for OSA and primary snoring were provided, then the OSA patients (AHI ≥ 5/h) were extracted for the meta-analysis. Data for AHI and LSAT were rounded to the nearest integer for simplification purposes in the tables; however, the actual calculations in this study were based on the raw data rounded to the nearest 10th decimal place value. If any additional data were needed for meta-analysis, then the plan was to contact the corresponding author at least twice to try to obtain the data.

Given that tonsillectomy can provide a significant improvement in AHI and LSAT based on a recent meta-analysis,[10] we planned to perform subanalyses based on whether a tonsillectomy or tonsillotomy was performed as a part of the procedure.

Quality Assessment of Included Studies

A modified version of the National Institute for Health and Clinical Excellence (NICE) quality assessment tool[11] was utilized for evaluating the included studies.

Statistics

The null hypothesis for this meta-analysis is that the pre- and post-LAUP sleep study and sleepiness data demonstrate no difference. STATA 14.1 (StataCorp, College Station, TX) and Review Manager Software (REVMAN) version 5.3 (Copenhagen: The Nordic Cochrane Centre: The Cochrane Collaboration, 2014) were utilized throughout this meta-analysis and the REVMAN obtained values were reported to the 100th decimal place value. A p-value < .05 was used as the cutoff for statistical significance. The magnitudes of effect for SMD were assigned using Cohen's guidelines[12] (small = 0.2, medium = 0.5, and large = 0.8).

A two-step subanalysis was performed on the individual patient, as described by Riley et al.[13] JMP 12 Pro was used to perform univariate analysis (two-tailed, paired t test) of the following variables to assess for predictors of surgical cure (<5 events/h), success (≥50% reduction in AHI and <20 events/h), and failure (more severe AHI or RDI post-op): age, gender, body mass index (BMI), pre-operative AHI, pre-operative RDI, pre-operative apnea index, and LSAT. The Bonferroni correction was applied to the interpretation of statistical significance due to the testing of multiple variables for each outcome, such that p = .002 was required to achieve significance. There was insufficient data to support multivariate analysis.

RESULTS

Study Selection/Characteristics

The systematic review of the literature provided a total of 767 potentially relevant studies. After screening the studies, 71 were downloaded for full-text review. Twenty-three studies met the predefined systematic review search criteria and were included in this meta-analysis, see Figure 1. All studies identified in the literature used in-lab, overnight polysomnography with the exception of Petri et al.[14] who used a portable monitor with electroencephalography. The included LAUP studies had a total of 717 patients with sleep study or sleepiness outcomes. The patients' average age was 50 ± 9 years, and the average BMI was 29 ± 4 kg/m^2. The total number of LAUP sessions in the studies ranged between 1 and 7 sessions. Table 1 summarizes the outcomes for the modified NICE quality assessment tool.

Sleep Study Outcomes

Apnea–Hypopnea Index

All Patients. There were 717 patients with AHI outcomes. Pre- and post-LAUP AHI means (*M*) ± *SD*s were available for 527 patients and showed a decrease from 28 ± 13 to 19 ± 12 events/h (relative percentage reduction of 32%), see Table 2. A subanalysis using random effects modeling for 519 patients demonstrated a MD of −6.56 [95% CI −10.14, −2.97] events/h, overall effect *Z* score = 3.59 (p = .0003), *Q* statistic p < .00001 (statistically significant heterogeneity), I^2 = 89% (high inconsistency), see Figure 2. Random effects modeling for 519 patients demonstrated a LAUP AHI SMD of −0.58 [95% CI −0.97, −0.18] (medium-sized effect), overall effect *Z* score = 2.88 (p = .004), *Q* statistic p < .00001 (statistically significant heterogeneity), I^2 = 88% (high inconsistency). A sensitivity analysis was performed for both MD and SMD and there was no specific study or group of studies that significantly reduced the heterogeneity.

LAUP With Palatopharyngoplasty. Petri et al.[14] performed a palatopharyngoplasty as part of the LAUP. They reported apnea index outcomes which reduced from 26 to 7 events/h (70% reduction).

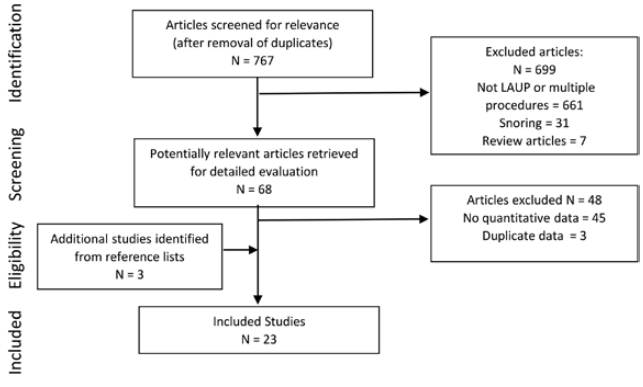

Figure 1—Study selection chart for LAUP studies. *N* = number of studies; LAUP = laser-assisted uvulopalatoplasty.

LAUP Without Tonsillectomy. There were 496 patients without tonsillectomy. Data could be combined in 336 patients, and the AHI decreased from a *M* ± *SD* of 22 ± 15 to 15 ± 15 events/h (relative percentage reduction: 32%), see Supplementary Table 1. A subanalysis using random effects modeling for these 336 patients demonstrated a MD of −5.80 [95% CI −9.87, −1.72] events/h, overall effect *Z* score = 2.79 (p = .005), *Q* statistic p < .00001 (statistically significant heterogeneity), I^2 = 91% (high inconsistency). The SMD for LAUP demonstrated a medium magnitude of effect for AHI (−0.68 [95% CI −1.25, −0.12]), overall all effect *Z* score = 2.36 (p = .02), *Q* statistic p < .00001 (statistically significant heterogeneity), and the I^2 = 91% (high inconsistency).

Unspecified if LAUP With Tonsillectomy. The AHI decreased in 10 patients from a *M* ± *SD* of 52 ± 25 to 45 ± 28 events/h (relative percentage reduction: 13%), see Supplementary Table 2.

LAUP With Tonsillectomy. The AHI decreased in 43 patients from a *M* ± *SD* of 54 ± 28 to 25 ± 14 events/h (relative percentage reduction: 54%), see Supplementary Table 2. A subanalysis using random effects modeling for these 43 patients demonstrated a MD of −29.84 [95% CI −39.05, −20.63] events/h, overall effect *Z* score = 6.35 (p < .00001), *Q* statistic p = .70 (no statistically significant heterogeneity), I^2 = 0% (no inconsistency). The SMD for LAUP demonstrated a large magnitude of effect for AHI (−1.30 [95% CI −1.79, −0.81]), overall effect *Z* score = 5.19 (p < .00001), *Q* statistic p = .31 (no statistically significant heterogeneity), and the I^2 = 5% (no to low inconsistency).

Mixed LAUP Surgeries (Mixed With and Without Tonsillectomy). The AHI decreased in 168 patients from a *M* ± *SD* of 33 ± 22 to 23 ± 16 events/h (relative percentage reduction: 30%), see Supplementary Table 2. A subanalysis using random effects modeling for 130 patients demonstrated a MD of −6.80 [95% CI −16.27, 2.67] events/h, overall effect *Z* score = 1.41 (p = .16), *Q* statistic p < .0001 (statistically significant heterogeneity), I^2 = 84% (high inconsistency). The SMD for LAUP demonstrated a small to medium magnitude of effect for AHI (−0.41 [95% CI −0.93, 0.11]), overall all effect *Z* score = 1.55 (p = 0.12), *Q* statistic p = .003 (statistically significant heterogeneity), and the I^2 = 75% (high inconsistency).

Oxygen Desaturation Index

Lin 2002 et al. reported outcomes for oxygen desaturation index, which improved in 25 patients from 35 ± 5 to 27 ± 12 events/h.

Lowest Oxygen Saturations

LSAT *M* ± *SD* were reported in 365 patients. LAUP improved LSAT from a *M* ± *SD* of 80 ± 8% to 82 ± 7%. A subanalysis using random effects modeling for all 365 patients demonstrated a MD of 1.27 [95% CI −0.17, 2.71] events/h, overall effect *Z* score = 1.73 (p = .08), *Q* statistic p = .02 (statistically significant heterogeneity), I^2 = 51% (medium level of inconsistency). The LSAT SMD was 0.25 [95% CI −0.06, 0.56] (small magnitude of effect), overall effect *Z*

Table 1—General Characteristics and Quality Criteria of Included Studies.

Authors, year	Study site	Design	Outcomes
Goktas, 2014	Germany	RCS	AHI, LAUP w/o T
Peng, 2009	China	RCS	AHI, LSAT, LAUP w/o T
Abdullah, 2008	Malaysia	RCS	AHI, LAUP w/wo T
Chisholm, 2007	England	PCS	AHI, ESS, LAUP w/wo T
Pavelec, 2006	Czech Republic	PCS	AHI, LAUP w/o T, 1 session
Atef, 2005	Egypt	PCS	AHI, LAUP w/o T, 1–5 sessions
Larrosa, 2004	Spain	RCT	AHI, ESS, LAUP w/o T, 1 session
Berger, 2003	Israel	PCS	RDI, LSAT, LAUP w/o T, 1–3 sessions
Ferguson, 2003	London	RCT	AHI, ESS, LAUP w/o T, 1–4 sessions
Kern, 2003	United States	RCS	AHI, LSAT, LAUP w/wo T
Finkelstein, 2002	Israel	PCS	RDI, LSAT, LAUP w/o T, 1–3 sessions
Lin, 2002	Taiwan	PCS	RDI, LSAT, LAUP w/wo T, 1 session
Seemann, 2002	Canada	PCS	RDI, AI, LAUP unsp T
Berger, 2001	Israel	PCS	RDI, LSAT, LAUP w/wo T, 1–2 sessions
Ryan, 2000	Canada	PCS	AHI, ESS, LSAT, LAUP w/o T, 1 session
Berger, 1999	Israel	PCS	RDI, LSAT, LAUP w/wo T, 1–3 sessions
Mickelson, 1999	United States	PCS	AHI, RDI, LSAT, LAUP w/wo T, 3 ± 1 sessions
Walker, 1999	United States	RCS	RDI, AHI, LSAT, LAUP w/o T, 1–7 sessions
Lauretano, 1997	United States	PCS	RDI, AHI, LSAT, LAUP w/o T, 3 ± 1 sessions
Hanada, 1996	Japan	PCS	AI, LSAT, LAUP w/o T
Skatvedt, 1996	Norway	PCS	AHI, LAUP w/o T, 1 session
Terris, 1996	United States	PCS	AI, HI, RDI, LAUP w/o T, 1 session
Petri, 1994	Denmark	PCS	AI, LAUPP w/wo T, 1 session

AHI = apnea–hypopnea index; AI = apnea index; ESS = Epworth Sleepiness Scale; HI = hypopnea index; LAUP = laser-assisted uvulopalatoplasty; LAUPP = laser-assisted uvulopalatopharyngoplasty; LSAT = lowest oxygen saturation; PCS = prospective case series; RCS = retrospective case series; RCT = randomized controlled trial; RDI = respiratory disturbance index; T = tonsillectomy; w/o = without; w/wo = with and without.

score = 1.58 (p = .12), Q statistic p < .0001 (statistically significant heterogeneity), I^2 = 74% (high inconsistency). A sensitivity analysis was performed for both MD and SMD and there was no specific study that was an outlier; however, removal of the studies by Walker et al., Lin et al., and Kern et al. resulted in no statistically significant heterogeneity and no inconsistency.

Risk of Bias

For AHI, the visual inspection of the funnel plots demonstrated a high risk of bias, with most studies being clustered toward the peak of the funnel for MD and SMD. For LSAT, the visual inspection of the funnel plots demonstrated a moderate risk of bias, with most studies being clustered toward the top half of the funnel for both MD and SMD.

Sleepiness

Sleepiness was quantified in 133 patients, see Supplementary Table 3. The ESS was reported in four studies with 70 patients, with an ESS pre- and post-LAUP $M \pm SD$ value of 12.4 ± 7.2 to 8.8 ± 3.9, respectively (54 patients with $M \pm SD$). A Likert scale was used by Mickelson et al.[15] reported outcomes for 36 patients using a 0–5 scale, in which 0 = no sleepiness and 5 = severe excessive daytime sleepiness, with a pre- and post-LAUP $M \pm SD$ value of 2.8 ± 1.2 and 1.6 ± 1.3, respectively. Skatvedt et al.[16] used a 0–10 scale in 16 patients in which 0 = asymptomatic and 10 = major problem, and sleepiness was 7.1 pre-LAUP and 2.1 post-LAUP. Walker et al.[17] found that in 11 patients who were falling asleep while driving pre-LAUP, 10 of the 11 (91%) had resolution after the LAUP.

Snoring

Snoring outcomes were quantified for 14 studies with 429 patients. There was significant heterogeneity in the manner in which the data were presented, with the highest number of studies reporting the visual analog scale (VAS) in which a 0 to 10 scale was used. The pre- and post-LAUP VAS for 158 patients was 8.4 ± 1.2 and 5.2 + 2.2, respectively. For most studies, snoring decreased (see Supplementary Table 3).

Table 2—Demographic and Sleep Study Data Pre- and Post-LAUP.

Study authors, year	*N*	Age	BMI	Pre-op AHI	Post-op AHI	AHI change**	Pre-op LSAT	Post-op LSAT
Goktas, 2014	23	63	30 ± 4	28 ± 17	25 ± 20	−12%	—	—
Peng, 2009	96	49	—	7–89	5–42	—	—	+10–33%
Abdullah, 2008	1	—	—	67	41	−39%	—	—
Chisholm, 2007	20	—	32 (28–38)	48 ± 20	13 ± 11	−73%	—	—
Pavelec, 2006	63	20–67	—	7 ± 6	5 ± 4	−32%	—	—
Atef, 2005	62	—	—	26 ± 10	11 ± 10	−58%	—	—
Larrosa, 2004	13	—	27 ± 2	14 ± 8	15 ± 18	+11%	—	—
Berger, 2003	25	50 ± 10	28 ± 3	25 ± 14	33 ± 23	+31%	88 ± 6	85 ± 9
Ferguson, 2003	21	—	—	19 ± 4	15 ± 8	−21%	—	—
Kern, 2003	64	43 ± 11	27 ± 4	51 ± 31	26 ± 21	−49%	77 ± 13	84 ± 10
Finkelstein, 2002	26	53 ± 10	28 ± 3	30 ± 22	25 ± 19	−16%	86 ± 9[a]	87 ± 8
Lin, 2002	25	41 ± 6	28 ± 2	40 ± 7	32 ± 14	−21%	71 ± 5	76 ± 9
Seemann, 2002	10	49	35	52 ± 25	45 ± 28	−13%	—	—
Berger, 2001	7	54 ± 7	26 ± 3	5 ± 0	7 ± 5	+29%	94 ± 6	94 ± 4
Ryan, 2000	44	49 ± 11	30 ± 4	29 ± 17	19 ± 15	−34%	78 ± 12	81 ± 9
Berger, 1999	10	49 (25–71)	29	13 ± 10	24 ± 10	+83%	83 ± 6	83 ± 7
Mickelson, 1999	36	52 ± 11	31 ± 8	28 ± 17	18 ± 14	−36%	81 ± 10	84 ± 7
Walker, 1999	40	53 ± 2	31 ± 1	25 ± 3	15 ± 3	−39%	84 ± 1	85 ± 1
Lauretano, 1997	17	—	—	27 ± 10	29 ± 10	+7%	88 ± 6	85 ± 7
Hanada, 1996	64	54 ± 10	—	14 ± 11[b]	9 ± 10[b]	−39%	72 ± 8	71 ± 8
Skatvedt, 1996	13	48 (26–63)	27 (21–37)	22 ± 24	8 ± 11	−75%	—	—
Terris, 1996	7	41 ± 13	—	11 ± 11	22 ± 10	+92%	88 ± 6	87 ± 4
Petri, 1994	30	47 (31–63)	28 (20–37)	26 (15–48)[b]	7 (2–23)[b]	−70%	—	—
Total[c]	717	50 ± 9	29 ± 4	28 ± 13	19 ± 12	−32%	80 ± 8	82 ± 7

AHI = apnea–hypopnea index; BMI = body mass index; LAUP = laser-assisted uvulopalatoplasty; LSAT = lowest oxygen saturation; *N* = number.
[a]Denotes calculation based on patients with pre- and post-operative data.
[b]Denotes apnea index.
[c]Total is based on means and standard deviations.
**AHI change is based on the weighted relative reduction in AHI pre- and post-LAUP.

Individual Patient Data

Nine articles reported pre- and post-operative AHI and/or RDI data for 226 individual patients.[18–26] Patients in these series who had tonsillectomy performed in addition to LAUP were excluded because there was only one study with stratified individual patient data available. Aggregate summary of individual patient data is shown in Table 3. There were statistically significant improvements to the AHI, RDI, apnea index, and LSAT post-LAUP. Overall, LAUP provided a surgical success (≥50% reduction to <20 events/h) in 23% and surgical cure (≥50% reduction to <5 events/h) in 8% of cases. Of note, the RDI (76/127) or AHI (23/99) was more severe post-operatively in 44% of cases (99/226). Univariate analysis showed that a pre-operative AHI <30 events/h was a significant predictor of surgical failure (pre-AHI <30 events/h: 37% [19/52] vs. pre-AHI ≥ 30: 9% [4/47], odds ratio 6 [2–20], $p = .0010$, Pearson's chi-square). The other variables tested as predictors of surgical success, cure, and failure did not reach statistical significance.

DISCUSSION

There are six main findings from this systematic review and meta-analysis. First, this review demonstrates that LAUP with or without tonsillectomy has not shown to consistently benefit patients with OSA. LAUP provided an AHI reduction of 32% when all included technique variations were combined. However, the improvements were limited as they achieved levels consistent with surgical success (≥50% reduction to <20 events/h) in only 23% and surgical cure (≥50% reduction to <5 events/h) in only 8% of cases. The mixed LAUP surgeries with or without tonsillectomy resulted in a significant relative reduction in AHI of 30%. Chisholm et al.[27] did demonstrate a more dramatic improvement in those who did not undergo a

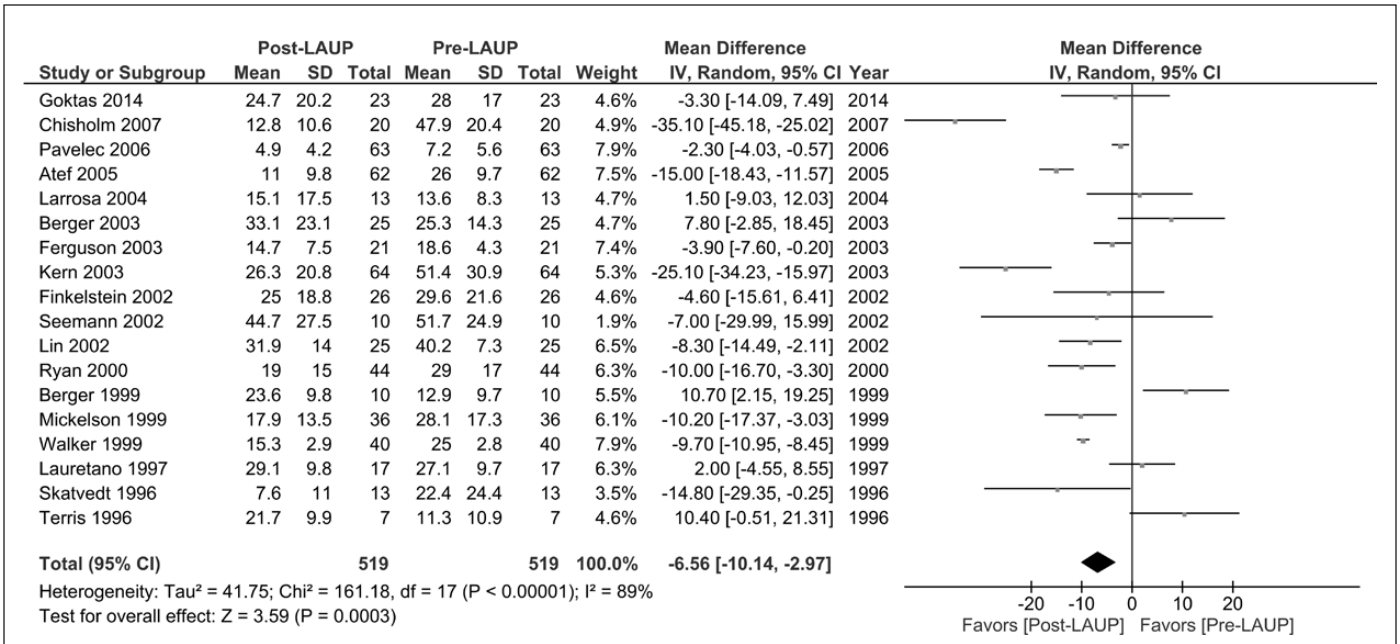

Figure 2.—Mean difference in AHI pre- and post-LAUP. 95% confidence intervals are provided. AHI = apnea–hypopnea index; LAUP = laser-assisted uvulopalatoplasty.

tonsillectomy, which is a result that is contradicted by the rest of the studies in this meta-analysis.

Second, LAUP does not consistently and reproducibly reduce RDI or AHI in adults with OSA regardless of technique. These findings are consistent with the study by Berger et al.[28] in which 4 of 14 patients (29%) who were primary snorers (defined as a pre-operative RDI of 5 or less) developed OSA after being treated with LAUP. An additional significant finding, which is concerning, is that the individual patient data demonstrated that 44% of patients worsened their RDI or AHI. The LSAT did not significantly improve clinically (80 ± 8% to 82 ± 7%) and the LSAT SMD between pre- and post-LAUP did not reach statistical significance ($p = .12$).

Third, despite the lack of consistent improvement in RDI and AHI, the patients' sleepiness improved in all included studies. The overall mean pre- and post-LAUP values for ESS decreased from 12.4 ± 7.2 to 8.8 ± 3.9, respectively. Although various sleepiness scales were used (Mickelson et al., Skatvedt et al., and Walker et al.), all the included studies demonstrated a decrease or resolution in sleepiness. Despite the improvements in ESS, the clinical relevance of the decrease in each individual study cannot be compared. When we compare the improvement in sleepiness after LAUP to those seen after an uvulopalatopharyngoplasty (UPPP), the improvement is generally higher for UPPP. For example, the improvement in ESS after LAUP was only 3 points, while after UPPP the improvement was nearly 6 points (randomized controlled trial performed by Browald et al.).[29] To further evaluate the effect of LAUP, a standardized scale to assess sleepiness such as ESS should be used, especially since Likert scales are generally different between studies.

Fourth, patients do demonstrate decreased snoring intensity after LAUP, which is likely secondary to scar tissue causing the soft palate to stiffen. Snoring is a sign of dynamic airway obstruction with vibration and turbulent airflow. By stiffening the palate and reducing the obstruction, there may be enough improvement in breathing to cause the patients to feel less sleepy. Despite the improvement in sleepiness, the fact remains that a large portion of the patients worsened their RDI and/or AHI after LAUP. The AASM's Practice Parameters for LAUP[5] notes that LAUP and UPPP are comparable with respect to relieving snoring. One problem with patients becoming quieter after LAUP, is that snoring is often a sign that patients may have OSA and therefore, in the AASM's Practice Parameters for LAUP,[5] the recommendation is that the patients undergo a sleep study prior to being considered for the procedure and also polysomnography periodically thereafter even if the patient was diagnosed with primary snoring and LAUP eliminates or reduces snoring.[5] We recommend that LAUP be performed with caution or not at all for primary snoring or OSA because of the potential to worsen the sleep-disordered breathing, as demonstrated by the unfavorable results seen in the currently published studies.

Fifth, this updated meta-analysis has similar findings to the meta-analysis of eight studies which was published in 2000 by Verse and Pirsig.[4] In their meta-analysis, LAUP improved the AHI in 232 patients from 29 to 23 events/h (21% reduction) and in this updated meta-analysis of 23 studies LAUP improved the AHI in 527 from 28 to 19 events/h (32% reduction). The AASM's Practice Parameters for LAUP[5] recommend that LAUP not be used to treat OSA. In this review, we recommend that LAUP be performed with caution or not be performed at all as treatment for OSA. Specifically, the individual patient data have demonstrated success rate of 23% and cure rate of 8%, but with a worsening of the RDI or AHI among 44% of patients. The worsening in such a high percentage of patients post-operatively is concerning.

Lastly, the effect of destroying the surface of the soft palate could potentially be worsening OSA severity. In the 1990s,

Table 3—Aggregate Summary of Individual Patient Data Pre- and Post-LAUP.

	Pre-LAUP	Post-LAUP	*p*-value
Characteristics			
Age (*n* = 109)	51 ± 11	NA	NA
Male gender (%) (*n* = 109)	84	NA	NA
BMI (kg/m^2) (*n* = 134)	29 ± 5	NA	NA
Follow-up (months) (*n* = 217)	24 ± 42	NA	NA
Sleep study data			
AHI (events/h) (*n* = 99)	35 ± 25	20 ± 17	
Mean difference	NA	−15 ± 3[a]	<.0001
RDI (events/h) (*n* = 127)	26 ± 21	22 ± 21	
Mean difference	NA	−4 ± 2[a]	.0172
Apnea index (events/h) (*n* = 59)	13 ± 14	5 ± 7	
Mean difference		−8 ± 2[a]	<.0001
LSAT (%)[b] (*n* = 132)	84 ± 10	86 ± 8	
Mean difference		2 ± 1[a]	.0258
Surgical success (AHI and RDI)[c]			
<20 events/h (%) (*n* = 226)	NA	22	NA
<15 events/h (%) (*n* = 226)	NA	20	NA
<10 events/h (%) (*n* = 226)	NA	14	NA
Surgical cure[c] (AHI and RDI)			
<5 events/h (%) (*n* = 226)	NA	8	NA
Surgical failure[c]			
Increased events/h after LAUP (%)	NA	44	

Plus-minus values are mean ± standard deviation except where noted. Values in parenthesis are the number of patients evaluated. AHI = apnea–hypopnea index; BMI = body mass index; LAUP = laser-assisted uvulopalatoplasty; LSAT = lowest oxygen saturation; NA = not applicable; RDI = respiratory disturbance index.
[a]Standard error of the mean is reported.
[b]The SpO_2 nadir is the lowest oxyhemoglobin saturation measured during sleep.
[c]Surgical cure defined as percent of subjects with <5 events/h and ≥50% reduction in AHI (or RDI) post-LAUP. Surgical success defined as the percent of subjects with <20, 15, or 10 events/h and a ≥50% reduction in the AHI (or RDI) post-LAUP. Surgical failure defined as post-operative AHI (or RDI) is more severe than pre-operative AHI (or RDI).

Friberg et al. biopsied the soft palates of non-snoring controls, habitual snorers, and OSA patients and demonstrated that progressive neurogenic lesions (an increased density in sensory nerve terminals) occur in habitual snorers (4 of 11 patients) and OSA patients (9 of 10 patients), when compared to controls.[30] A second study by Friberg et al. found that there were a significantly increased number of atrophied and/or hypertrophied fibers in OSA patients, consistent with neurogenic lesions.[31] Additionally, studies have demonstrated that there is a reflexogenic dilation of the pharyngeal airway, which is at least partially mediated by pharyngeal mucosa afferent nerve fibers. Therefore, it is possible that by destroying the surface of the soft palate whether by laser or other techniques (cautery-assisted palatal stiffening operations [CAPSO]), that we are blunting the reflexogenic dilation of the pharyngeal airway during sleep. This phenomenon appears likely to worsen OSA or even induce OSA in the case of some primary snorers. Given the availability of mucosal sparing techniques currently available (ie, radiofrequency ablation, tissue-sparing UPPP,[32] etc.), we recommend that techniques that destroy soft palate mucosa be used with caution or not performed at all. Further, if the procedure is performed that patients be properly counseled of the findings in this and other reviews.[5]

LIMITATIONS

First, the majority of studies in the literature regarding LAUP did not provide sleep study data. Therefore, an assumption is that the articles reviewed in this study accurately reflect the outcomes of patients who have undergone LAUP. Second, not all the studies published individual patient data; however, 226 patients did have individual patient data available for evaluation. Lastly, only two studies were randomized controlled trials while most of the studies were case series (no control group), and all analyses were uncontrolled comparisons of pre-LAUP to post-LAUP outcome. Therefore, this meta-analysis is based on case series analysis only. The meta-analyses mostly showed significant heterogeneity and high inconsistency among the LAUP studies. Only studies of LAUP with tonsillectomy showed insignificant heterogeneity and no/low inconsistency, likely due to tonsillectomy having a consistent effect on improving outcomes (as supported by this meta-analysis findings and a different tonsillectomy-only meta-analysis[10]).

CONCLUSION

In this meta-analysis, LAUP reduced AHI by 32% among all patients; while the LSAT only changed minimally. Individual data demonstrated a success rate of 23%, cure rate of 8%, and worsening of the AHI among 44% of patients. We recommend that LAUP be performed with caution or not performed at all given the unfavorable results of currently published studies.

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