Referral of Adults with Obstructive Sleep Apnea for Surgical Consultation

An American Academy of Sleep Medicine systematic review, meta-analysis, and GRADE assessment

David Kent, MD[1]; Jeffrey Stanley, MD[2]; R. Nisha Aurora, MD, MHS[3]; Corinna Levine, MD, MPH[4]; Daniel J. Gottlieb, MD[5]; Matthew D. Spann, MD[1]; Carlos A. Torre, MD[4]; Katherine Green, MD, MS[6]; Christopher G. Harrod, MS (for the American Academy of Sleep Medicine)[7].

[1]Vanderbilt University Medical Center, Nashville, TN; [2]University of Michigan, Ann Arbor, MI; [3]Rutgers Robert Wood Johnson Medical School, New Brunswick, NJ; [4]University of Miami, Miller School of Medicine, Miami FL; [5]Brigham and Women's Hospital, VA Boston Healthcare System, Boston, MA; [6]University of Colorado, Aurora, CO; [7]American Academy of Sleep Medicine, Darien, IL.

Introduction: The purpose of this systematic review is to provide supporting evidence for a clinical practice guideline on the referral of adults with obstructive sleep apnea (OSA) for surgical consultation.

Methods: The American Academy of Sleep Medicine commissioned a task force of experts in sleep medicine. A systematic review was conducted to identify studies that compared the use of surgery with no treatment as well as studies that reported on patient-important outcomes pre- and postoperatively. Statistical analyses were performed to determine the clinical significance of using surgery to treat obstructive sleep apnea in adults. Finally, the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) process was used to assess the evidence for making recommendations.

Results: The literature search resulted in 254 studies that provided data suitable for statistical analyses. The analyses demonstrated that surgery as a rescue therapy results in a clinically significant reduction in sleepiness, snoring, blood pressure (BP), apnea-hypopnea index (AHI), respiratory disturbance index (RDI), oxygen desaturation index (ODI), increase in lowest oxygen saturation (LSAT), and improvement in quality of life in adults with OSA who refused, failed, or are intolerant to positive airway pressure (PAP) therapy. The analyses demonstrated that surgery as an adjunctive therapy results in a clinically significant reduction in optimal PAP pressure and improvement in PAP adherence in adults with OSA who fail or are intolerant to PAP due to side effects associated with high pressure requirements. The analyses also demonstrated that surgery as a first-line treatment results in a clinically significant reduction in AHI/RDI, sleepiness, snoring, BP, and ODI, and increase in LSAT in adults with OSA and major anatomical obstruction. Analysis of bariatric surgery data showed a clinically significant reduction in BP, AHI/RDI, sleepiness, snoring, optimal PAP level, BMI, ODI, and an increase in LSAT in adults with OSA and obesity. Analyses of very limited evidence suggest that upper airway surgery does not result in a clinically significant increase in risk of serious persistent adverse events, and also suggested that bariatric surgery may result in a clinically significant risk of iron malabsorption that may be managed with vitamin supplements. The task force provided a detailed summary of the evidence along with the quality of evidence, the balance of benefits and harms, patient values and preferences, and resource use considerations.

INTRODUCTION

This systematic review is intended to provide supporting evidence for a clinical practice guideline on the referral of adults with OSA for surgical consultation to treat obstructive sleep apnea (OSA) in adults and update the evidence review conducted for the previously published American Academy of Sleep Medicine (AASM) guideline.[1] The 2010 systematic review[2] compared the efficacy of different surgical procedures to inform recommendations for specific surgical procedures. This review was designed to determine if surgical therapies for OSA are effective for improving outcomes of interest when analyzed collectively, which will inform recommendations for when sleep clinicians should discuss referral to a sleep or bariatric surgeon with adults with OSA.

BACKGROUND

OSA is a common chronic disease characterized by repetitive upper airway collapse, with resultant oxyhemoglobin desaturations and arousals. The prevalence of OSA is high and is expected to continue to rise in tandem with the obesity epidemic. Based on data from the Wisconsin Sleep Cohort, it is estimated that 34% of men and 17% of women age 30-70 years have at least mild OSA, while 13% of men and 6% of women in this age range have moderate-to-severe OSA, with prevalence increasing with age.[3] The adverse consequences of untreated OSA can be seen at many levels. Untreated OSA is associated with cardiometabolic consequences such as hypertension, atrial fibrillation, heart failure, ischemic heart disease, and type 2 diabetes, although the causal nature of these associations has yet to be conclusively established.[3, 4] Untreated OSA has a negative impact on patient-centered outcomes, with reduced quality of life (QOL) observed on both generic and disease-specific health questionnaires. The reduction in QOL is mediated primarily by excessive daytime sleepiness,[5] which is also implicated as the cause of workplace absenteeism and decreased productivity,[6] and motor vehicle crashes[7] seen in individuals with OSA.

Positive airway pressure (PAP) has remained first-line therapy for all severities of symptomatic OSA since its initial description as a treatment for OSA in 1981.[8] Extensive evidence from randomized clinical trials has demonstrated a beneficial effect of PAP therapy on sleepiness, QOL, and blood pressure (BP)[9, 10]; however, adherence to PAP therapy is difficult for many patients, with an overall reported non-adherence rate ranging from 20-40%.[11-14] Evidence suggests that patients with moderate to severe OSA and only partial nightly adherence to PAP therapy may continue to experience moderate to severe disease burden, even when meeting CMS requirements for adherence.[15] Other therapeutic medical options for OSA include lifestyle modifications, such as exercise, weight loss, and avoidance of agents that can affect upper airway patency, like alcohol. Mandibular repositioning appliances[16] and positional therapy[17] are also effective treatment modalities in appropriate patient subsets. For many OSA patients, a more definitive treatment that does not involve ongoing external equipment use may be preferable. Surgical modifications of the upper airway have been a part of the armamentarium for OSA treatment since the 1970's. Initially, tracheostomy was the sole surgical option available, although acceptance was limited due to associated social and lifestyle challenges. In 1981, Fujita introduced uvulopalatopharyngoplasty (UPPP) in the United States, the first specialized surgical procedure specifically designed to treat OSA.[18]

By 1996, several additional surgical procedures for treatment of OSA were available, and the initial systematic review and practice parameter on surgical modifications of the upper airway for adults with OSA was published by the American Sleep Disorders Association, now known as the American Academy of Sleep Medicine (AASM). The AASM updated the original systematic review[2] and original practice parameters[1] in 2010. The review focused on individual surgical interventions and their available data such as UPPP, modified UPPP, other pharyngeal procedures, laser assisted uvulopalatoplasty, upper airway radiofrequency treatment, soft palatal implants, multi-level simultaneous surgeries, and multi-level phased surgeries. The primary outcome was the apnea-hypopnea index (AHI), as many study investigators defined surgical success as a 50% reduction in AHI to a level less than 20 events/hr (i.e., definition of mild OSA prior to 1999). While these previous systematic reviews and guidelines recognized the evolution in surgical techniques, the role of the surgeon in identifying appropriate interventions and providing in-depth patient counseling in their area of expertise was not explicitly addressed. The task force additionally sought to evaluate patient-centered outcomes more formally than had been done in prior systematic reviews. Looking beyond upper airway surgery, the amassing evidence surrounding the impact of weight loss surgery on OSA also necessitated review of bariatric surgery as a potential OSA treatment option.

The AASM recognized that current management guidelines do not address the critical question of when to consider discussing surgical treatment options with adults with OSA. The AASM chose to focus the current systematic review and accompanying recommendations[19] on when to discuss referral to a sleep or bariatric surgeon with adults with OSA rather than evaluating specific surgical procedures. The purpose of the current systematic review is to inform clinical care by considering specific, commonly encountered clinical scenarios in which discussion of a referral for sleep or bariatric surgery consultation may provide patient benefit, while acknowledging that the training and depth of surgical knowledge needed for appropriate anatomic evaluation and patient counseling are outside the practice boundaries of most sleep medicine providers.

METHODS

Expert Task Force

The AASM commissioned a task force (TF) comprised of both board-certified sleep medicine specialists and experts with proficiency in the use of surgery in adults with OSA to develop this systematic review. The TF was required to disclose all potential conflicts of interest (COI) per the AASM's COI policy prior to being appointed to the TF, and throughout the research and writing of this paper. In accordance with the AASM's COI policy, TF members with a Level 1 conflict were not allowed to participate. TF members with a Level 2 conflict were required to recuse themselves from any related discussion or writing responsibilities. All relevant COI are listed in the Disclosures section.

PICO Questions

PICO (**P**atient, **I**ntervention, **C**omparison, and **O**utcomes) questions were developed based on a review of the existing AASM practice parameters on the use of surgery and a review of systematic reviews, meta-analyses, and guidelines published since 2010. The AASM Board of Directors (BOD) approved the final list of PICO questions presented in **Table 1** before the literature search was performed. To develop the PICO questions, the TF identified patient populations that could benefit from surgery as well as a list of patient-oriented, clinically relevant outcomes to determine if and when referral of adults with OSA for surgical consultation should be discussed by the sleep clinician. The TF rated the relative importance of each outcome to determine which outcomes were critical versus important for decision-making. A summary of these outcomes by PICO is presented in **Table 2**.

The TF set a clinical significance threshold (CST) for each outcome to determine whether the mean changes in the outcomes assessed were clinically significant based on their clinical expertise, other AASM guidelines, and available literature. The CST was defined as the minimum level of improvement in the outcome of interest that would be considered clinically important to clinicians and patients. A summary of the CSTs for the clinical outcome measures is presented in **Table 3**. CSTs were determined based on a TF literature review of commonly used thresholds. When no clearly established threshold values could be determined, the TF used their clinical judgment and experience to establish a CST based on consensus.

Table 1 - PICO Questions

1	**Population:** Adult OSA patients who are intolerant or unaccepting of PAP therapy **Intervention:** Upper airway surgery as a salvage treatment **Comparison:** No surgery **Outcomes:** excessive sleepiness, snoring, sleep-related quality of life (QOL), motor vehicle accident (MVA) risk, AHI/RDI, oxygen desaturation index (ODI), lowest oxygen saturation (LSAT), PAP adherence/acceptance, perioperative death, permanent dysphagia
2	**Population:** Obese adult OSA patients who are intolerant or unaccepting of PAP therapy **Intervention:** Bariatric surgery **Comparison:** No bariatric surgery or best medical care

	Outcomes: excessive sleepiness, snoring, sleep-related QOL, MVA risk, AHI/RDI, PAP adherence/acceptance, optimal PAP level, BP, ODI, LSAT, perioperative death, permanent dysphagia, body mass index (BMI)
3	**Population:** Adult OSA patients who have persistent suboptimal PAP adherence due to pressure-related side effects **Intervention:** Upper airway surgery as an adjunctive treatment to PAP **Comparison:** No adjunctive surgery **Outcomes:** excessive sleepiness, snoring, sleep-related QOL, PAP adherence/acceptance, optimal PAP level, perioperative death, permanent dysphagia
4	**Population:** Adult OSA patients with tonsillar hypertrophy and/or craniofacial abnormalities **Intervention:** Upper airway surgery as an initial treatment **Comparison:** No surgery **Outcomes:** excessive sleepiness, snoring, sleep-related QOL, MVA risk, blood pressure (BP), AHI/RDI, ODI, LSAT, perioperative death, permanent dysphagia

Table 2 –Outcomes by PICO Question

Outcomes	PICO Question #			
	1	2	3	4
Sleepiness	√	√	√	√
Adherence to PAP Therapy			√	
Optimal PAP level		√*	√	
Quality of Life	√	√	√	√
AHI/RDI	√	√	√*	√
Lowest oxygen saturation	√*	√*	√*	√
Oxygen desaturation index	√*	√*		√
Snoring	√	√*	√	√
Blood Pressure	√	√		√*
Perioperative death	√	√		√
Permanent dysphagia	√			√
BMI		√*		
Motor vehicle accidents		√*		√*

*Outcomes considered important but not critical for decision-making

Table 3 – Summary of Clinical Significance Thresholds for Outcome Measures

Outcome Measure[1]	Clinical Significance Threshold*†
AHI/RDI	-10%
Adherence to PAP therapy	0.5 hours/night; 10% patient use >4 hours/night[9, 20, 21]
Self-reported sleepiness ESS	--- 2 points[22-24]
Quality of Life FOSQ SAQLI SF-36 (Physical Component Summary) (Mental Component Summary) (Vitality Summary)	--- 1 point[9, 21] 1 point[9, 21] --- 3 points[25] 3 points[25] 12.5 points[26]
Blood Pressure SBP DBP	--- 2 mm Hg[27, 28] 1 mm Hg[27, 28]
Snoring	---

VAS Frequency	25% 10%
Lowest oxygen saturation	5%
Perioperative death	Any reduction
Permanent dysphagia Risk difference MD Anderson score	--- 5% 10 points[29]
Obesity BMI	--- -2 kg/m^2
Optimal PAP level	-1 cm H_2O
PAP adherence	+0.5 hrs/night[9, 20, 21]
PAP acceptance	10% patients used
Motor Vehicle Crashes	Risk ratio of 0.9 (-10%)[30-32]

[1]AHI – apnea/hypopnea index; RDI – respiratory disturbance index; ESS – Epworth sleepiness score; FOSQ – functional outcome of sleep questionnaire; SAQLI – Calgary sleep apnea quality of life index; SF-36 - Short form - 36 item; PSQI – Pittsburgh sleep quality index; SBP – systolic blood pressure; DBP – diastolic blood pressure; VAS – visual analog scale; BMI – body mass index; CPAP – continuous positive airway pressure
*References used to inform task force consensus
† The clinical significance thresholds are for comparison of pre- versus post-treatment effects as well as between surgery and control.

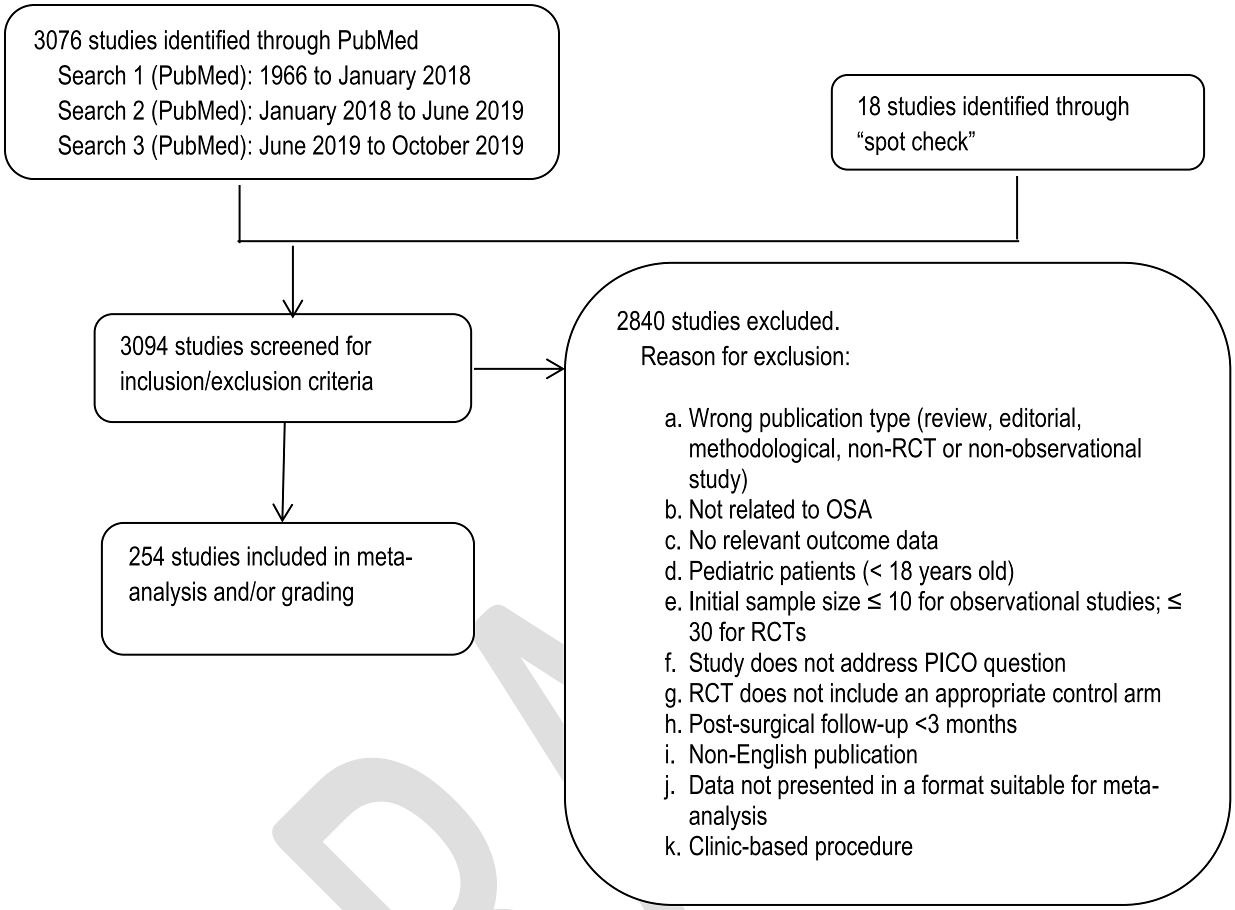
Literature Searches, Evidence Review and Data Extraction

The TF performed an extensive review of the scientific literature to retrieve articles that addressed the PICO questions. Separate literature searches were performed by the TF for each PICO question using the PubMed database (see **Figure 1**). The key terms, search limits, and inclusion/exclusion criteria specified by the TF are detailed in the supplemental material.

The initial literature search of English publications in PubMed was performed in January 2018. In June 2019, the TF performed a second literature search specifically targeting the use of hypoglossal nerve stimulation to treat adults with OSA. A third search was performed in October 2019 to update the evidence prior to publication. These searches identified a total of 3,076 articles. Lastly, the TF reviewed previously published guidelines, systematic reviews, and meta-analyses to spot check for references that may have been missed during the prior searches. The TF identified 18 additional articles for a total of 3,094 articles that were screened for inclusion/exclusion in the guideline.

The TF set inclusion and exclusion criteria, which are presented in the supplemental material and summarized in **Figure 1.** All studies were reviewed based on inclusion/exclusion criteria by two TF members. Any discrepancies between the reviewers were discussed and resolved by the two reviewers or a third TF member. A total of 254 studies were determined to be suitable for meta-analysis and/or grading.

Figure 1 – Evidence Base Flow Diagram



Meta-Analysis

Meta-analysis was performed on outcomes of interest, when possible, for each PICO question. Comparisons of surgery to no treatment and/or assessment of efficacy before and after surgery to treat OSA in adult patients were performed. For the purposes of this review, meta-analyses were only performed on operating room-based surgical procedures. These procedures included tonsillectomy, adenoidectomy, uvulopalatopharyngoplasty (UPPP), modified UPPP, maxillomandibular advancement (MMA), anterior palatoplasty, rhinoplasty, z-palatoplasty, z-palatopharyngoplasty, expansion sphincter pharyngoplasty, transoral robotic surgery, tongue base reduction, tongue base suspension, hyoid myotomy, hyoid suspension, lingual suspension, lingualplasty, hyoidthyroidpexia, genioglossal advancement, bimaxillary osteotomy, glossectomy, pharyngoplasty, endoscopic sinus surgery, septal surgery, septorhinoplasty, turbinate surgery, nasal surgery, oropharyngeal surgery, velopharyngeal surgery, multilevel surgery, bilateral endoscopic total ethmoidectomy, bilateral endoscopic middle meatal antrostomy, hypoglossal nerve stimulation, gastric bypass, gastric banding, and sleeve gastrectomy. Clinic-based procedures were excluded from meta-analysis.

Meta-analysis was performed using Review Manager 5.3 software by pooling data across studies for each outcome measure. Post-treatment data were used for meta-analysis of RCTs, except where change values were reported. Pre- and postsurgical treatment data were used for meta-analyses of observational studies. The pooled results for each continuous outcome measure were expressed as the mean difference between the intervention and control for RCTs or pre-surgery versus post-surgery for observational studies. The pooled results for dichotomous outcome measures were expressed as the odds ratio or risk difference between the intervention and comparator or pre-surgery versus post-surgery. All analyses were performed using a random effects model with results displayed as a forest plot. Interpretation of clinical significance for the outcomes of interest was conducted by comparing the mean difference in effect of each treatment approach to the CST (see **Table 3**). Meta-analyses performed for PICOs 1,2, and 4 included any operating room-based procedure. Meta-analyses performed for PICO 3 included 2 sub-groups consisting of craniofacial and oropharyngeal surgical procedures. This analysis was performed to determine if specific subgroups (i.e., patients with craniofacial abnormalities vs tonsillar hypertrophy) would respond more favorably to surgery as a first-line treatment.

GRADE Assessment for Developing Recommendations

The assessment of evidence quality was performed according to the Grading of Recommendations Assessment, Development and Evaluation (GRADE) process.[33, 34] The TF assessed the following four components to determine the direction and strength of a recommendation: quality of evidence, balance of beneficial and harmful effects, patient values and preferences, and resource use, as described below.

1. Quality of evidence – based on an assessment of the overall risk of bias (randomization, blinding, allocation concealment, selective reporting), imprecision (95% confidence interval crosses the CST and/or sample size <100 participants), inconsistency (I^2 ≥50%), indirectness (study population vs target patient population), and risk of publication bias, the TF determined their overall confidence that the estimated effect found in the body of evidence was representative of the true treatment effect that typical adult patients with OSA would see. The quality of the evidence was based on outcomes that the TF deemed critical for decision making; important outcomes are not considered when determining the overall quality of evidence.

2. Benefits vs. Harms – based on the meta-analysis of harmful outcomes (if data were available), analysis of any harms/side effects reported within the accepted literature and the clinical expertise of the TF, the TF determined if the beneficial outcomes of the intervention outweighed any harmful side effects.

3. Patient values and preferences – based on the clinical expertise of the TF members and any data published on the topic relevant to patient preferences, the TF determined if patient values and preferences would be generally consistent across the majority of patients, and if patients would use the intervention based on the relative harms and benefits identified.

4. Resource use – based on the clinical expertise of the TF members, the TF judged resource use to be important for determining whether to recommend the use of surgery for the treatment of adults with OSA.

A summary of each GRADE domain is provided after the detailed evidence review.

Public Comment and Final Approval

A draft of the guideline and systematic review was made available for public comment for a four-week period on the AASM website. The TF took into consideration all the comments received and made decisions about whether to revise the draft based on the comments. The revised guideline and systematic review were submitted to the AASM BOD for subsequent approval. This review reflects the state of knowledge at the time of publication and will be reviewed and updated as new information becomes available.

THE USE OF SURGICAL INTERVENTION

The aims of the current literature reviews and data analyses were focused on addressing 4 questions pertaining to the use of surgery to treat OSA in adults. Below are detailed summaries of the evidence identified in the literature searches and the statistical analyses performed by the TF. Each evidence summary is accompanied by a discussion of the quality of evidence, balance of benefits and harms, patient values and preferences, and resource use considerations that contributed to the development of the recommendations provided in the accompanying clinical practice guideline.[19]

Surgical treatment of patients who are intolerant or unaccepting of PAP

A total of 3 RCTs[35-37] and 220 observational studies[35-258] investigated the use of surgery as rescue therapy for participants who were intolerant or unaccepting of PAP to improve one or more of the following outcomes: excessive sleepiness, quality of life (QOL), snoring, blood pressure (BP), perioperative death, permanent dysphagia, apnea-hypopnea index (AHI), respiratory disturbance index (RDI), lowest oxygen saturation (LSAT), and oxygen desaturation index (ODI). Participants in the RCTs had moderate to severe OSA and received UPPP with or without tonsillectomy. Participants in the control group originally received no treatment but were eventually treated with the same procedure(s). Participants in the observational studies represented a broad population of adults undergoing a wide variety of surgical interventions for OSA including palatal modification, tongue base resection, multilevel pharyngeal airway surgery, nasal surgery, maxillomandibular advancement, and hypoglossal nerve stimulation. Most observational studies were retrospective cohort studies with reassessment of participants at approximately 6-months postoperatively, though some followed participants out to about 1 year. A large range of sleep apnea severity was represented with most participants having moderate to severe OSA. Participants were primarily middle-aged or elderly, and most cohorts were composed of predominantly men. Participants tended to be overweight or mildly obese. A variety of upper airway surgical procedures including palatal modification, base of tongue reduction, skeletal modification, nasal surgeries, multilevel surgeries, tracheostomy, and hypoglossal nerve stimulation were performed in an operating room setting. All participants were evaluated for improvement in outcomes after 3 months and up to 1 year after surgery. Meta-analyses were performed to assess the efficacy of surgery as a rescue therapy for adults with OSA. The meta-analyses are provided in the supplemental material, **Figure S1** through **Figure S31**. A summary of findings table is provided in the supplemental material, **Table S1**. A summary of the evidence for each outcome is provided below.

Critical Outcomes

The following outcomes were determined by the TF to be critical for evaluating the efficacy of surgery as a rescue therapy: sleepiness, QOL, AHI/RDI, snoring, BP, perioperative death, and permanent dysphagia. Meta-analyses for AHI/RDI included all definitions as reported in the studies. None of the studies identified in our literature review reported data for perioperative death.

SLEEPINESS: The efficacy of rescue surgery to reduce excessive sleepiness was evaluated using a meta-analysis of 2 RCTs.[36, 37] Participants in the 2 RCTs[36, 37] had moderate to severe OSA. Participants in both RCTs[36, 37] received UPPP, but one RCT[37] also included UPPP with tonsillectomy. Participants in the control group originally received no treatment but were eventually treated with the same procedure(s). The meta-analysis demonstrated a clinically significant reduction in excessive sleepiness of -4.8 points (95% CI: -7.0 to -2.6 points) as measured by the ESS (see supplemental material, **Figure S1**). The quality of evidence was moderate due to imprecision associated with small sample size.

The efficacy of rescue surgery to reduce excessive sleepiness was also evaluated using a meta-analysis of 128 observational studies.[38, 39, 41-45, 47-50, 52, 54-56, 59, 61, 65-68, 70-72, 74, 76, 77, 84-86, 88-91, 93-95, 98, 100, 103, 107, 109, 110, 113, 115, 117-120, 122, 124-126, 130, 133, 134, 136, 137, 141-143, 145-150, 153, 159, 161, 162, 165-175, 177, 178, 184-187, 189-198, 200, 205, 206, 208, 213-215, 217, 219-221, 223, 227, 231-237, 239, 240, 242, 243, 247, 248, 251-253, 259] Participants represented a broad population of PAP-intolerant adults, primarily middle-aged or elderly, of predominantly male gender with moderate to severe OSA who underwent a wide variety of surgical interventions as listed above. The meta-analysis demonstrated a clinically significant reduction in excessive sleepiness of -5.8 points (95% CI: -6.3 to -5.4 points) as measured by the ESS (see supplemental material, **Figure S2**). The quality of evidence was low due to risk of bias associated with observational studies.

QOL/SLEEP QUALITY: The efficacy of rescue surgery to improve sleep-related QOL was evaluated using a meta-analysis of 9 observational studies[64, 107, 131, 176, 220, 231, 243, 247, 248] that reported on the Functional Outcome of Sleep Questionnaire (FOSQ). Most of the participants were older men with moderate to severe OSA who refused or were intolerant to PAP therapy and underwent a variety of surgical interventions; the majority of which consisted of hypoglossal nerve stimulation (HNS). The meta-analysis demonstrated a clinically significant improvement in sleep related QOL of 3.4 points (95% CI: 3.0 to 3.8 points) with rescue surgery as measured by the FOSQ (see supplemental material, **Figure S3**). The quality of evidence was low due to risk of bias associated with observational studies.

The efficacy of rescue therapy to improve sleep quality was evaluated based on a meta-analysis of 3 observational studies[133, 195, 249] that reported on the Pittsburgh Sleep Quality Index (PSQI). The participants were mostly male, aged 19-66 years, with mild to moderate OSA, who underwent either oropharyngeal[121, 183] or nasal surgery[237] and were followed from 3 to 39 months. The meta-analysis demonstrated an improvement that was not clinically significant (see supplemental material, **Figure S4**). The quality of evidence was low due to risk of bias associated with observational studies.

One observational study prospectively evaluated the efficacy of rescue therapy to improve sleep apnea-related QOL as measured by the Sleep Apnea-Related QOL Index (SAQLI).[98] The participants, who were mostly male, aged 35 to 73 years, with moderate to severe OSA and intolerant to CPAP, underwent HNS and were followed for 6 months. An analysis of the study[98] demonstrated an improvement in sleep apnea related QOL as measured by the SAQLI that was not clinically significant (see supplemental material, **Figure S5**). The quality of evidence was very low due to risk of bias associated with observational studies and imprecision associated with small sample size and a wide 95% confidence interval that crossed the clinical significance threshold (CST).

The efficacy of rescue therapy to improve general QOL was evaluated based on an analysis of 1 RCT[36] that reported on the SF-36 component summary scores. The participants in the RCT[36] that reported on the SF-36 component summary scores included CPAP-intolerant older men with moderate to severe OSA and significant daytime sleepiness undergoing palatal surgery or observation. Participants were followed for approximately 7 months. The efficacy of rescue therapy to improve general QOL was also evaluated based on an analysis of 1 observational study[146] that reported on the SF-36 component summary scores. The participants included older CPAP-intolerant men, 23-70 years of age with severe OSA and an average BMI of 26.4 kg/m^2. These participants underwent palatal modification surgery and were followed for approximately 6 months after surgery.

An analysis of 1 RCT[36] demonstrated an improvement in general QOL that was not clinically significant as measured by the SF-36 physical component score (see supplemental material, **Figure S6**). The quality of evidence was moderate due to imprecision associated with small sample size and a wide 95% confidence interval that crossed the CST.

An analysis of 1 observational study[146] demonstrated a clinically significant improvement in general QOL of 10.8 points (95% CI: 2.2 to 19.4 points) with rescue therapy as measured by the SF-36 physical component summary score (see supplemental material, **Figure S7**). The quality of evidence was very low due to risk of bias associated with observational studies, and imprecision associated with small sample size and a wide 95% confidence interval that crossed the CST.

An analysis of 1 RCT[36] demonstrated a clinically significant improvement in general QOL of 5.4 points (95% CI: 0.1 to 10.7 points) with rescue therapy as measured by the SF-36 mental component score (see supplemental material, **Figure S8**). The quality of evidence was moderate due to imprecision associated with small sample size and a wide 95% confidence interval that crossed the CST.

An analysis of 1 observational study[146] demonstrated a clinically significant improvement in general QOL of 15.7 points (95% CI: 7.2 to 24.2 points) with rescue therapy as measured by the SF-36 mental component score (see supplemental materials, **Figure S9)**. The quality of evidence is very low due to risk of bias associated with observational studies, and imprecision associated with small sample size.

An analysis of 1 RCT[36] demonstrated a clinically significant decrease in general QOL of -21.1 points (95% CI: -32.7 to -9.5 points) with rescue therapy as measured by the SF-36 vitality score (see supplemental material, **Figure S10**). The quality of evidence was moderate due to imprecision associated with small sample size and a wide 95% confidence interval that crossed the CST.

An analysis of 1 observational study[146] demonstrated a clinically significant improvement in general QOL of 13.8 points (95% CI: 7.9 to 19.7 points) with rescue therapy as measured by the SF-36 vitality score (see supplemental materials, **Figure S11)**. The quality of evidence is very low due to risk of bias associated with observational studies and imprecision associated with small sample size and a wide 95% confidence interval that crossed the CST.

SNORING: The efficacy of rescue surgery to improve snoring was evaluated using an analysis of 1 RCT[37] that reported on snoring as measured on a 1-10 visual analog scale (VAS). Most of the participants were male, aged 18 to 65 years with a baseline BMI < 35 kg/m^2 and moderate to severe OSA. All patients were CPAP intolerant and had an oropharyngeal obstruction. All patients had follow-up at 3 months after surgery. The analysis demonstrated a clinically significant decrease in snoring of -3.7 points (95% CI: -5.3 to -2.1 points) with rescue surgery as measured on a 1-10 VAS (see supplemental material, **Figure S12**). The quality of evidence was moderate due to imprecision associated with small sample size and a wide 95% confidence interval that crossed the CST.

The efficacy of rescue surgery to improve snoring was also evaluated using a meta-analysis of 36 observational studies[38, 41, 42, 45, 56, 70, 72, 85-87, 95-97, 103, 113, 118, 134, 145, 150, 162, 165-168, 172, 191-194, 208, 227, 242, 243, 251, 252, 254] that reported on snoring as measured on a 1-10 VAS in adults with OSA. Most of the participants were male, aged 18 to 69 years with a baseline BMI < 33 kg/m^2. While several of the studies included participants with mild and moderate OSA, most of the participants had severe OSA. The duration of patient follow-up after surgery ranged from 3 to 62 months. The meta-analysis demonstrated a clinically significant reduction in snoring of -5.2 points (95% CI: -5.9 to -4.6) with rescue surgery as measured by the 1-10 VAS in adults with OSA (see supplemental material, **Figure S13**). The quality of evidence was low due to risk of bias associated with observational studies.

BLOOD PRESSURE: The efficacy of rescue surgery to reduce BP was evaluated using a meta-analysis of 10 observational studies.[83, 117, 135, 142, 143, 178, 194, 197, 205, 240] The observational studies included retrospective, and prospective cohort and case-control designs. Most of the participants were male, aged 18 to 69 years with a baseline BMI < 35 kg/m^2 and moderate to severe OSA. The duration of patient follow-up after surgery ranged from 3 to 12 months.

The efficacy of rescue surgery to reduce systolic blood pressure (SBP) was evaluated using a meta-analysis of 10 observational studies.[83, 117, 135, 142, 143, 178, 194, 197, 205, 240] The meta-analysis demonstrated a clinically significant reduction in SBP of -6.3 mm Hg (95% CI: -11.6 to -0.9 mm Hg) with rescue therapy in adult patients with OSA (see supplemental material, **Figure S14**). The quality of evidence was very low due to risk of bias associated with observational studies and imprecision associated with a wide 95% confidence interval that crossed the CST.

The efficacy of rescue surgery to reduce diastolic blood pressure (DBP) was evaluated using a meta-analysis of 9 observational studies.[83, 117, 135, 142, 143, 178, 194, 197, 240] The meta-analysis demonstrated a clinically significant reduction in DBP of -2.7 mm Hg (95% CI: -7.9 to 2.5 mm Hg) with rescue therapy in adults with OSA (see supplemental material, **Figure S15**). The quality of evidence was low due to risk of bias associated with observational studies.

AHI/RDI: The AHI and RDI are commonly reported as measures of OSA severity. The efficacy of rescue surgery to reduce the AHI was evaluated using a meta-analysis of 2 RCTs.[35, 37] Most of the participants were male, aged 18 to 65 years with a baseline BMI < 34 kg/m^2. The duration of patient follow-up after surgery ranged from 3 to7 months. While several of the studies included participants with moderate OSA, most of the participants had severe OSA. The meta-analysis demonstrated a clinically significant reduction in OSA severity as measured by the AHI of -18.7 events/hr (95% CI: -32.9 to -4.5 events/hr) with rescue surgery (see supplemental materials, **Figure S16**). The quality of evidence was moderate due to imprecision associated with small sample size.

The efficacy of rescue surgery to reduce the AHI was evaluated using a meta-analysis of 177 observational studies.[38, 40-50, 52-63, 65-78, 81, 83-93, 96, 97, 99-104, 106-110, 112-117, 119, 121-124, 126-133, 135-137, 140-142, 145, 147-149, 155, 159-161, 163, 164, 166-169, 171-174, 176-180, 183-186, 188, 189, 191, 193, 195-198, 200, 204-206, 208-215, 217, 218, 220-224, 226-230, 233-239, 241, 242, 244-257, 260] Most of the participants were male, aged 19 to 78 years with a baseline BMI < 42 kg/m^2. The duration of patient follow-up after surgery ranged from 3 to 60 months. While several of the studies included participants with mild OSA, most of the participants had moderate to severe OSA. The meta-analysis demonstrated a clinically significant reduction in the AHI of -24.1 events/hr (95% CI: -25.8 to -22.4 events/hr) representing a 59% reduction with rescue surgery (see supplemental materials, **Figure S17**). The quality of evidence was moderate due to risk of bias associated with observational studies and large effect size.

The efficacy of rescue surgery to reduce the RDI was evaluated using a meta-analysis of 2 RCTs.[35, 37] Most of the participants were male, aged 18 to 65 years with a baseline BMI < 34 kg/m^2. The duration of patient follow-up after surgery ranged from 3 to 7 months. While several of the studies included participants with moderate OSA, most of the participants had severe OSA. The meta-analysis demonstrated a clinically significant reduction in the RDI of -16.4 events/hr (95% CI: -33.3 to 0.6 event/hr) with rescue surgery (see supplemental material, **Figure S18**). The quality of evidence was moderate due to imprecision associated with small sample size and a wide 95% confidence interval that crossed the CST.

The efficacy of rescue surgery to reduce the RDI was evaluated using a meta-analysis of 26 observational studies.[48, 79, 99, 111, 118, 143, 144, 151, 152, 154, 156-158, 170, 181, 182, 190, 192, 193, 195, 202, 203, 216, 219, 225, 227] The observational studies included retrospective, and prospective cohort and case-control designs. Most of the participants were male, aged 21 to 61 years with a baseline BMI < 50 kg/m^2. The duration of patient follow-up after surgery ranged from 3 to 50 months. While several of the studies included participants with mild OSA, most of the participants had moderate to severe OSA. The meta-analysis demonstrated a clinically significant reduction in the RDI of -33.4 events/hr (95% CI: -38.7 to -28.2 events/hr) representing a 70% reduction with rescue surgery (see supplemental material, **Figure S19**). The quality of evidence was moderate due to risk of bias associated with observational studies and large effect size.

PERMANENT DYSPHAGIA: The risk of permanent dysphagia from upper airway surgery was evaluated using a meta-analysis of 7 observational studies[105, 115, 136, 172, 192, 203, 244] that reported on persistent long-term dysphagia. The observational studies included retrospective, and prospective cohort designs. The participants were mostly male, ranged from 18-73 years of age, with moderate to severe OSA who underwent a variety of surgical procedures including palatal modification, tonsillectomy, multilevel, maxillomandibular advancement, and tongue base suspension. The meta-analysis demonstrated that the risk of permanent dysphagia was not clinically significant (see supplemental materials, **Figure S20**). The quality of evidence was very low due to risk of bias associated with observational studies, and imprecision associated with a wide 95% confidence interval that crossed the CST.

The risk of permanent dysphagia was also evaluated from an analysis of 1 observational study[237] that reported on the MD Anderson dysphagia score after upper airway surgery. The participants were mostly male, ranged from 29-65 years of age, with moderate to severe OSA who underwent either transoral robotic surgery with expansion sphincter pharyngoplasty or transoral robotic surgery with UPPP. The analysis demonstrated a change in the MD Anderson dysphagia score after surgery that was not clinically significant (see supplemental materials, **Figure S21**). The quality of evidence was very low due to risk of bias associated with observational studies, and imprecision associated with small sample size and a wide 95% confidence interval that crossed the CST.

Important Outcomes

The following outcomes were determined by the TF to be important outcomes but not critical for evaluating the efficacy of this intervention: LSAT, and ODI.

LOWEST OXYGEN SATURATION: The efficacy of rescue surgery to increase the LSAT was evaluated using a meta-analysis of 2 RCTs.[35, 37] Most of the participants were male, aged 18 to 65 years with a baseline BMI < 35 kg/m^2, had severe OSA, and underwent palatal modification surgery. The duration of participant follow-up ranged from 4 to 7 months. The meta-analysis demonstrated an increase in the LSAT that was not clinically significant with rescue surgery (see supplemental material, **Figure S22**). The quality of evidence was moderate due to imprecision associated with small sample size and a wide 95% confidence interval that crossed the CST.

The efficacy of rescue surgery to increase the LSAT was also evaluated using a meta-analysis of 124 observational studies[41-44, 46-48, 54-57, 60-62, 66, 70, 72, 74-76, 80-82, 85-91, 97, 101, 103, 109, 111-113, 117-120, 122-127, 130-135, 138, 141-143, 148, 153, 156-161, 164-169, 171-174, 176-179, 181-183, 189-191, 193, 195-197, 199, 201-204, 207-210, 215-217, 219, 220, 222, 223, 225-227, 230, 232, 234, 236, 239, 241, 242, 244, 245, 249, 252, 253, 258, 261] that reported on the LSAT. The observational studies included retrospective, and prospective cohort and case-control designs. Most of the participants were male, aged 19 to 73 years with a baseline BMI <40 kg/m^2. The duration of participant follow-up ranged from 3 to 36 months. While several of the studies included participants with mild OSA, most of the participants had moderate to severe OSA. The meta-analysis demonstrated a clinically significant increase in the LSAT of 7.3% (95% CI: 6.4 to 8.2%) with rescue surgery (see supplemental material, **Figure S23**). The quality of evidence was low due to risk of bias associated with observational studies.

OXYGEN DESATURATION INDEX: The efficacy of rescue surgery to decrease the ODI was evaluated using an analysis of 1 RCT.[35] Most of the participants were male, with a mean age of 43 years, a baseline BMI < 36 and Friedman stage I or II who underwent palatal modification surgery. The mean duration of participant follow-up was 7 months. While several of the studies included participants with moderate OSA, most of the participants had severe OSA. Analysis of the study[35] demonstrated a clinically significant decrease in the ODI of -21.6 events/hr (95% CI: -30.2 to -13.0 events/hr) with rescue surgery (see supplemental material, **Figure S24**). The quality of evidence was moderate due to imprecision associated with small sample size.

The efficacy of rescue surgery to decrease the ODI was also evaluated using a meta-analysis of 41 observational studies.[49, 51, 55, 56, 60, 65, 66, 82, 98-100, 103, 108, 109, 127, 133, 137-139, 142, 143, 173-175, 184-186, 188, 195, 198, 206, 208, 220, 221, 230, 231, 233, 235, 244, 247, 248, 262] The observational studies included retrospective, and prospective cohort and case-control designs. Most of the participants were male, ranged from 20 to 80 years of age, a BMI <40 kg/m^2 with mild to severe OSA who underwent a variety of surgical procedures. The duration of participant follow-up ranged from 3 months to 4 years. The meta-analysis demonstrated a clinically significant decrease in the ODI of -16.9 units (95% CI: -19.7 to -14.2 units) representing a 56% reduction with rescue surgery (see supplemental material, **Figure S25**). The quality of evidence was moderate due to risk of bias associated with observational studies and large effect size.

Overall quality of evidence

The TF determined that the overall quality of evidence for the use of surgical treatments in patients who are intolerant or unaccepting of PAP was low based on the critical outcomes and downgrading of the evidence due to risk of bias associated with observational studies, and imprecision within the RCTs (see supplemental material, **Table S1**).

Benefits vs harms

The potential benefits of upper airway surgery as a rescue therapy include a reduction in sleepiness, snoring, blood pressure, and AHI/RDI, and an improvement in QOL in patients intolerant to PAP therapy. Benefits demonstrated in literature are limited to patients appropriate for surgery. This may not be representative of all OSA patients. The potential harms of upper airway surgery include short-term discomfort that is expected during post-operative recovery and is discussed during the preoperative informed consent process between the surgeon and patient. Additionally, potential persistent long-term side effects have been reported including dysphagia, taste alteration, mandibular paresthesia, perceived worsening of facial appearance, aspiration, hemorrhage, and globus pharyngeus, but the incidence of these is low. The incidence of perioperative death was not reported in the studies. A meta-analysis of 5 observational studies[39, 105, 148, 169, 203] demonstrated a risk in persistent taste alteration that was not clinically significant (see supplemental material, **Figure S26**). A meta-analysis of 7 observational studies[64, 101, 157, 172, 181, 202, 203] demonstrated a clinically significant risk of persistent mandibular paresthesia of 0.11 (95% CI: 0.03 to 0.19) with surgery (see supplemental material, **Figure S27**). An analysis of 1 prospective cohort study[64] demonstrated a risk in persistent perceived worsening of facial appearance that was not clinically significant (see supplemental material, **Figure S28**). An analysis of 1 prospective cohort study[203] demonstrated a clinically significant risk in persistent aspiration of 0.05 (95% CI: -0.01 to 0.11) with surgery (see supplemental material, **Figure S29**). An analysis of 1 retrospective study[105] demonstrated a risk in persistent hemorrhage that was not clinically significant (see supplemental material, **Figure S30**). An analysis of 1 retrospective study[113] demonstrated a risk in persistent globus pharyngeus that was not clinically significant (see supplemental material, **Figure S31**). Based on their combined clinical experience and the substantial effects of surgery on objective and subjective measures of disease, the TF judged that the potential benefits of a discussion regarding referral to a sleep surgeon with patients intolerant or unaccepting of PAP therapy outweigh the potential harms of untreated OSA. The TF observed that the balance of risks versus benefits for upper airway surgery is variable and dependent upon an individual patient's OSA severity, symptoms, medical comorbidities, and selected surgical therapy, but notes that a discussion of individualized risks and benefits is a standard component of the preoperative informed consent process.

Resource use

There are insufficient data to assess differences in resource requirements for surgery versus PAP therapy or no treatment.

Patient values and preferences

Because acceptability of surgical interventions varies and there is little harm in discussing a referral for consultation, based on their combined clinical experience, the TF judged that most patients would generally be accepting of a discussion regarding referral. The choice to pursue referral is expected to vary between patients based on personal values, beliefs, and expectations for recovery time or pain with surgery.

Surgical treatment of patients with obesity with bariatric surgery

A total of 3 RCTs[263-265] and 28 observational studies[201, 263, 266-292] investigated the use of bariatric surgery to improve one or more of the following outcomes: blood pressure, AHI/RDI, sleepiness, BMI, ODI, LSAT, optimal PAP pressure, PAP adherence, snoring, motor vehicle accident risk, and perioperative death. For the RCTs,[263-265] participants were randomized to either bariatric surgery or nutritional care. Participants were obese, ranged from 18 to 65 years of age with a BMI > 35 kg/m^2 and severe OSA who were treated with laparoscopic adjustable gastric banding (LAGB) and followed for a period ranging from 2-3 years. All participants received CPAP therapy prior to surgery. For the observational studies,[201, 266-292] comparisons between pre- and posttreatment were made. Participants were mostly female, 20 to 66 years of age, obese, with a mean BMI > 30 kg/m^2 and mild to severe OSA. The participants underwent a variety of bariatric procedures including gastric banding, gastric bypass, and sleeve gastrectomy and were typically followed for 1 year (range: 6 months to 5 years) after surgery. The observational studies included retrospective, and prospective cohort and case-control designs. All procedures were performed in an operating room setting. Several meta-analyses were performed to assess the efficacy of bariatric surgery to treat OSA in adults. The meta-analyses are provided in the supplemental material, **Figure S32** through **Figure S47**. A Summary of Findings table is provided in the supplemental material, **Table S2**. A summary of the evidence for each outcome is provided below.

Critical Outcomes

The following outcomes were determined by the TF to be critical for evaluating the efficacy of bariatric surgery to treat OSA in adults with obesity: sleepiness, QOL, AHI/RDI, BP, and permanent dysphagia. Meta-analyses for AHI/RDI included all definitions as reported in the studies. None of the studies identified in our literature review reported data for perioperative death.

BLOOD PRESSURE: The efficacy of bariatric surgery to lower BP was evaluated using a meta-analysis of 5 observational studies.[268, 269, 272, 279, 291] The studies included both prospective cohort and case-control designs.

Participants were mostly female, 26-60 years of age, with a BMI > 31 kg/m^2 and moderate to severe OSA. The participants underwent either gastric banding or gastric bypass and were followed from a range of 6 months to 2 years after surgery. The meta-analyses demonstrated a clinically significant decrease in SBP and DBP of -9.3 mm Hg (95% CI: -14.3 to -4.3 mm Hg) and -6.9 mm Hg (95% CI: -10.2 to -3.6 mm Hg), respectively, with bariatric surgery (see supplemental materials, **Figure S32** and **Figure S33**). The quality of evidence was low due to risk of bias associated with observational studies.

AHI/RDI: The AHI and RDI are commonly reported as measures of OSA severity. The efficacy of bariatric surgery in reducing the AHI in adults with obesity was evaluated using a meta-analysis of 3 RCTs.[263-265] Participants were randomized to bariatric surgery or nutritional care. Participants were mostly male, obese, ranged from 18 to 65 years of age, with a BMI > 35 kg/m^2 and severe OSA, who were treated with LAGB and followed for a period ranging from 2-3 years. All participants received CPAP therapy prior to surgery. The meta-analysis demonstrated a clinically significant mean difference in the AHI of -12.2 events/hr (95% CI: -20.9 to -3.5 events/hr) with bariatric surgery compared with conservative nutritional care (see supplemental material, **Figure S34**). The quality of evidence was moderate due to imprecision associated with a wide 95% confidence interval that crossed the CST.

The efficacy of bariatric surgery in reducing the AHI in adults with obesity was also evaluated using a meta-analysis of 20 observational studies.[201, 266-268, 270-272, 274, 276, 278-280, 282, 283, 285-289, 291, 292] Participants were mostly female, obese, 20 to 66 years of age, with a mean BMI > 35 kg/m^2 and moderate to severe OSA. The participants were treated with a variety of procedures including gastric banding, gastric bypass, or sleeve gastrectomy and followed for a period ranging from 6 months to 5 years. A meta-analysis of 20 observational studies[201, 266-268, 270-272, 274, 278-280, 282, 283, 285-289, 291, 292] demonstrated a clinically significant mean difference in the AHI of -23.1 events/hr (95% CI: -29.0 to -17.2 events/hr) representing a 66% reduction with bariatric surgery as measured by the AHI (see supplemental material, **Figure S35**). The quality of evidence was moderate due to risk of bias associated with observational studies, and large effect size.

The efficacy of bariatric surgery in reducing the RDI in adults with obesity was evaluated using a meta-analysis of 2 observational studies.[267, 276] Participants were mostly female, middle-aged, with a BMI >35 kg/m^2 who underwent gastric bypass surgery and were followed for 6-42 months. The meta-analyses demonstrated a clinically significant difference in the RDI of -36.3 events/hr (95% CI: -40.6 to -32.0 events/hr) for a reduction of 71% with bariatric surgery (see supplemental material, **Figure S36**). The quality of evidence was moderate due to risk of bias associated with observational studies and large effect size.

SLEEPINESS: The efficacy of bariatric in reducing excessive sleepiness in adults with obesity and OSA was evaluated using a meta-analysis of 9 observational studies[271, 272, 276, 282, 283, 285, 290-292] that reported on the ESS. The observational studies included retrospective and prospective cohort designs. Participants were mostly female, 20-66 years of age, with mean BMI of > 31 kg/m^2 and moderate to severe OSA. The meta-analysis demonstrated a clinically significant reduction in excessive sleepiness as measured by the ESS of -5.6 points (95% CI: -7.3 to -3.9 points) with bariatric surgery (see supplemental material, **Figure S37**). The quality of evidence was moderate due to risk of bias associated with observational studies, and large effect size.

The efficacy of bariatric surgery in reducing excessive sleepiness in adults with obesity and OSA was also evaluated using an analysis of 1 very large case-control study[275] that reported on the frequency of daytime sleepiness. Participants in the study were mostly female, mean age of 47 years, with a mean BMI of < 43 kg/m^2 and OSA of unknown severity. Participants in the surgery group underwent a variety of procedures including gastric bypass, vertical banded gastroplasty, or gastric banding and were followed for 2 years. Participants in the control group underwent a conservative weight loss program. The analysis demonstrated a clinically significant reduction in the odds of experiencing daytime sleepiness of 0.4 (95% CI: 0.35 to 0.5) with bariatric surgery as compared with a conservative weight loss program (see supplemental material, **Figure S38**). The quality of evidence was low due to risk of bias associated with observational studies.

Important Outcomes

The following outcomes were determined by the TF to be important outcomes but not critical for evaluating the efficacy of bariatric surgery to treat OSA in adults with obesity: optimal PAP level, LSAT, ODI, snoring, BMI, and motor vehicle accidents. None of the studies identified in our literature review reported data for PAP adherence or motor vehicle accidents.

BMI: The efficacy of bariatric surgery in reducing BMI in adults with obesity and OSA was evaluated using an analysis of 1 RCT[265] that reported on BMI. Participants were randomized to LAGB or nutritional care. The RCT included participants (21 M:16 F) with OSA ranging from moderate to severe, a BMI > 35 kg/m^2, and no significant comorbidities who used PAP therapy prior to surgery. The duration of follow-up after surgery was 2 years. The analysis demonstrated a clinically significant reduction in BMI of -10.4 kg/m^2 (95% CI: -15.3 to -5.5 kg/m^2) with bariatric surgery compared with conservative nutritional care (see supplemental material, **Figure S39**). Additionally, one RCT that reported on absolute weight loss instead of change in BMI demonstrated a clinically meaningful reduction in weight of -22.7 kg (95%: -30.9 to -14.5 kg) with bariatric surgery compared with nutritional care.[263] The quality of evidence was moderate due to imprecision associated with small sample size.

The efficacy of bariatric surgery in reducing BMI in adults with obesity and OSA was also evaluated using 25 observational studies[201, 266-274, 276-288, 291, 292] that reported on BMI. The observational studies included retrospective, and prospective cohort and case-control designs. Participants were mostly female, 20 to 66 years of age, with a mean BMI > 30 kg/m^2, and mild to severe OSA. The participants underwent a variety of bariatric procedures including gastric banding, gastric bypass, and sleeve gastrectomy and were typically followed for 1 year (range: 6 months to 5 years) after surgery. The meta-analysis demonstrated a clinically significant reduction in BMI of -12.8 kg/m^2 (95% CI: -14.3 to -11.4 kg/m^2) with bariatric surgery (see supplemental material, **Figure S40**). The quality of evidence was moderate due to risk of bias associated with observational studies, and large effect size.

OXYGEN DESATURATION INDEX: The efficacy of bariatric surgery in reducing the ODI was evaluated using a meta-analysis of 5 observational studies.[201, 267, 280, 291, 292] The observational studies included retrospective and prospective cohort designs. Participants ranged in age from 20-66 years with mild to severe OSA, and a BMI > 30 kg/m^2. Both genders were nearly equally represented across all studies. The participants underwent LAGB or gastric bypass and were followed for 6 months to 2 years. The meta-analysis demonstrated a clinically significant reduction in the ODI of -19.1 events/hr (95% CI: -25.0 to -13.3 events/hr) representing a 73% reduction with bariatric surgery (see supplemental materials, **Figure S41**). The quality of evidence for ODI was moderate due to risk of bias associated with observational studies, and large effect size.

LOWEST OXYGEN SATURATION: The efficacy of bariatric surgery in increasing the LSAT was evaluated using a meta-analysis of 9 observational studies.[201, 267, 274, 276, 278, 279, 282, 291, 292] The studies included retrospective and prospective cohort designs. Participants were mostly female, aged 20-66 years with moderate to severe OSA, and a BMI > 25 kg/m^2. The participants underwent LAGB or gastric bypass and were followed for 6 months to 2 years. The meta-analysis demonstrated a clinically significant increase in LSAT of 7.8% (95% CI: 6.0 to 9.6%) with bariatric surgery (see supplemental materials, **Figure S42**). The quality of evidence was low due to risk of bias associated with observational studies.

OPTIMAL PAP LEVEL: The efficacy of bariatric surgery to lower PAP level requirements to facilitate future PAP use was evaluated using a meta-analysis of 3 observational studies.[276, 281, 282] The studies included retrospective and prospective cohort designs. Participants were mostly female with mild to severe OSA, and a BMI > 40 kg/m^2 who were prescribed CPAP prior to surgery. Participants underwent either LAGB or gastric bypass and were followed for 1-2 years. The meta-analysis demonstrated a clinically significant decrease in optimal CPAP level of -3.1 cm H_2O (95% CI: -4.2 to -1.9 cm H_2O) with bariatric surgery (see supplemental material, **Figure S43**). The quality of evidence for optimal CPAP level was very low due to risk of bias and imprecision associated with small sample size.

SNORING: The efficacy of bariatric surgery to decrease snoring was evaluated using an analysis of 1 prospective observational cohort study[267] that reported on the percentage of patients snoring before and after surgery. Participants had a mean age of 39±10 years, a BMI > 35 kg/m^2, with moderate to severe OSA who underwent gastric bypass surgery and were followed for mean of 14 months. Both genders were equally represented. Analysis demonstrated a clinically significant reduction in the percentage of patients snoring of -37.8% (95% CI: -60.9 to -14.7%) with bariatric surgery (see supplemental material, **Figure S44**). The quality of evidence was very low due to risk of bias associated with observational studies and imprecision associated with small sample size.

The efficacy of bariatric surgery to decrease snoring was also evaluated using a meta-analysis of 2 observational studies[275, 282] that reported on snoring frequency. Participants were mostly female, 30-60 years of age, with a BMI > 35 kg/m^2 and moderate to severe OSA who underwent gastric bypass, vertical banded gastroplasty, or gastric banding and were followed for 1-2 years. The meta-analysis demonstrated a clinically significant decrease in the odds of snoring of 0.4 (95% CI: 0.03 to 5.10) with bariatric surgery (see supplemental materials, **Figure S45**). The quality of evidence was very low due to risk of bias associated with observational studies, and imprecision associated with a wide 95% confidence interval that crossed the CST.

Overall quality of evidence

The TF determined that the overall quality of evidence for the use of bariatric surgery in patients with obesity and OSA was moderate due to risk of bias and large effect size associated with the observational studies, and imprecision within the RCTs (see supplemental material, **Table S2**).

Benefits vs harms

The benefits of bariatric surgery in patients with obesity and OSA include a reduction in AHI/RDI, BP, ODI, sleepiness, BMI, snoring, and optimal CPAP level, and an increase in the LSAT. Benefits demonstrated in literature are limited to patients considered appropriate for bariatric surgery by the treating surgeon and may not be representative of all OSA patients with obesity. While the benefits of bariatric surgery are clinically significant, the surgeon needs to consider factors that would make a patient at higher risk of surgical intervention, which are not captured by this analysis. Selection bias may be present in the observed outcomes as compliance with lifestyle changes are required of patients undergoing bariatric surgery. It is difficult to determine whether the effects of bariatric surgery on BP and ESS are directly attributed to weight loss from surgery or the lowering of AHI. Bariatric surgery is therefore not considered a cure for OSA. Potential harms of bariatric surgery, including short-term perioperative discomfort, and this should be discussed as part of the preoperative informed consent process between the surgeon and patient. Additionally, iron malabsorption, gastric ulcer, vitamin deficiency, bowel obstruction or leak, gastrointestinal reflux disorder, and gastric band slippage have been reported but the incidence of these is low. However, 1 observational study[274] demonstrated a clinically significant increase in the risk difference in iron malabsorption of 0.08 (-0.12 to 0.29) after bariatric surgery (see supplemental material, **Figure S46**). Analysis of 1 RCT[264] demonstrated a risk difference in incidence of gastric ulcer that was not clinically significant after bariatric surgery compared with conservative weight loss (see supplemental material, **Figure S47**). Based on their combined clinical experience and the substantial effects of bariatric surgery on objective and subjective measures of disease, the TF judged that the potential benefits of a discussion regarding referral to a bariatric surgeon with patients who are intolerant or unaccepting of PAP therapy outweigh the potential harms of untreated OSA. The TF observed that the balance of risks versus benefits for bariatric surgery is highly dependent upon an individual patient's OSA severity, symptoms, medical comorbidities, and selected surgical therapy, but notes that a discussion of individualized risks and benefits is a standard component of the preoperative informed consent process.

Resource use

There is insufficient evidence in the literature to compare the costs of bariatric surgery to nutritional care or untreated OSA.

Patient values and preferences

Because acceptability of surgical interventions varies and there is little harm in discussing referral, based on their combined clinical experience the TF judged that most patients would generally be accepting of a discussion regarding referral. The choice to pursue referral is expected to vary between patients based on personal values, beliefs, and expectations for recovery time or pain with surgery.

Surgical treatment of patients to facilitate PAP use

A total of 7 observational studies[44, 54, 132, 189, 229, 258, 293] investigated the use of surgery as an adjunctive procedure to facilitate the use of PAP by improving one or more of the following outcomes: optimal PAP level, sleepiness, adherence, AHI/RDI, sleep-related QOL, and LSAT. Three of the studies[44, 132, 258] were retrospective and 4 of the studies[54, 189, 229, 293] were prospective cohorts. Participants in the studies were mostly male, 23-66 years of age, with a mean BMI <32 kg/m^2 and moderate to severe OSA who underwent a variety of surgical procedures including nasal, tonsil, and palatal modification procedures and were offered CPAP after surgery. Most of the participants were intolerant to CPAP prior to surgery. In all studies CPAP titration was performed before and after surgery. All procedures were performed in an operating room and patients were followed for a period ranging from 3 to 12 months. Meta-analyses were performed to assess the efficacy of surgery as an adjunctive treatment of OSA in adults. The meta-analyses are provided in the supplemental material, **Figure S48** through **Figure S52**. A summary of findings table is provided in the supplemental material, **Table S3**. A summary of the evidence for each outcome is provided below.

Critical Outcomes

The following outcomes were determined by the TF to be critical for evaluating the efficacy of surgery as an adjunctive procedure to facilitate the use of PAP by improving one or more of the following outcomes: sleepiness, adherence to PAP therapy, optimal PAP level, QOL, and snoring. None of the studies identified in our literature review reported data for QOL or snoring.

OPTIMAL PAP LEVEL: The efficacy of adjunctive surgery to reduce the optimal PAP level was evaluated using a meta-analysis of 6 observational studies.[44, 132, 189, 229, 258, 293] Baseline characteristics of the participants are described above. The meta-analysis demonstrated a clinically significant reduction in optimal CPAP level of -2.5 cm H_2O (95% CI: -3.5 to -1.4 cm H_2O) with adjunctive surgery (see supplemental material, **Figure S48**). The quality of evidence was low due to risk of bias associated with observational studies.

SLEEPINESS: The efficacy of adjunctive surgery to reduce excessive sleepiness was evaluated using a meta-analysis of 3 observational studies.[44, 54, 189] The observational studies included retrospective and prospective cohort designs. Participants were mostly male, 29-63 years of age with a mean BMI <32 kg/m^2 and moderate to severe OSA who were intolerant to CPAP prior to multilevel,[44] tonsillectomy,[189] and nasal[54] surgery. Participants were followed for a range of 3-6 months after surgery. The meta-analysis demonstrated a clinically significant decrease in sleepiness as measured by a change in ESS by -6.0 points (95% CI: -7.2 to -4.7 points) with adjunctive surgery (see supplemental material, **Figure 49**). The quality of evidence was low due to risk of bias associated with observational studies.

PAP ADHERENCE: The efficacy of adjunctive surgery to improve PAP adherence was evaluated using a meta-analysis analysis of 2 prospective cohort studies.[229, 293] Participants were mostly male, 31-66 years of age with severe OSA who underwent modified tongue base suspension[229] or multilevel surgery[293] to facilitate CPAP use and were followed for a range of 3-6 months. One study[229] included participants with no prior CPAP use while the other study[293] included participants who were intolerant to CPAP. The meta-analysis demonstrated a clinically significant increase in CPAP adherence of 2.2 hrs/night (95% CI: 0.2 to 4.1 hrs/night) with adjunctive surgery (see supplemental material, **Figure S50**). The quality of evidence was very low due to risk of bias associated with observational studies, and imprecision associated with small sample size and a wide 95% confidence interval that crossed the CST.

Important Outcomes

The following outcomes were determined by the TF to be important outcomes but not critical for evaluating the efficacy of surgery as an adjunctive procedure to facilitate the use of PAP by improving one or more of the following outcomes: AHI/RDI, and LSAT. Meta-analyses for AHI/RDI included all definitions as reported in the studies.

AHI/RDI: The efficacy of adjunctive surgery to reduce the AHI severity was evaluated using a meta-analysis of 5 observational studies.[44, 132, 189, 229, 293] Participants were mostly male, 31-66 years of age with a mean BMI <32 kg/m^2 and moderate to severe OSA who underwent multilevel[44, 293] or palatal modification[132, 189, 229]surgery and were followed for a range of 3 to 12 months. The meta-analysis demonstrated a clinically significant reduction in the AHI of -22.9 events/hr (95% CI: -33.9 to -11.9 events/hr) for a 41% reduction (see supplemental material, **Figure S51**). None of the studies reported on the RDI. The quality of evidence was low due to risk of bias associated with observational studies.

LOWEST OXYGEN SATURATION: The efficacy of adjunctive surgery to increase the LSAT was evaluated using a meta-analysis of 2 prospective cohort studies.[189, 293] Participants in the studies were mostly male, 23-54 years of age, with severe OSA who underwent multilevel[293] or palatal modification[189] surgery and were followed for 3-4 months and 6 months, respectively.

Meta-analysis of 2 observational studies demonstrated a clinically significant increase in the LSAT of 10.4 % (95% CI: 7.0 to 13.8%) as measured by PSG (see supplemental materials, **Figure S52**). The quality of evidence was very low due to risk of bias associated with observational studies, and imprecision associated with small sample size and a wide 95% confidence interval that crossed the CST.

Overall quality of evidence

The TF determined that the overall quality of evidence for the use of surgical treatments to facilitate PAP use was very low based on the critical outcomes and downgrading of the evidence due to risk of bias associated with observational studies, and imprecision within the RCTs (see supplemental material, **Table S3**).

Benefits vs harms

The potential benefits of upper airway surgery as an adjunctive procedure to facilitate effective PAP therapy include a reduction in optimal PAP level, sleepiness, and AHI/RDI, as well as an increase in PAP adherence and LSAT. Benefits demonstrated in literature were limited to patients considered appropriate for surgery by the treating surgeon and may not be representative of all patients with PAP-related side effects or suboptimal use. The potential harms of upper airway surgery include short-term discomfort that is expected during post-operative recovery and is discussed during the informed preoperative consent process between the surgeon and patient. Surgery carries inherent risks but, based on their combined clinical experience and the moderate effects of surgery on PAP pressure requirements and adherence, the TF judged that the potential benefits of a discussion regarding referral to a sleep surgeon for consideration of surgery as an adjunctive procedure to facilitate PAP use may, in some patients, outweigh the potential harms of suboptimal PAP-related side effects and adherence depending on their severity. If referral is discussed, the TF observed that the balance of risks versus benefits for upper airway is highly dependent upon an individual patient's OSA severity, symptoms, medical comorbidities, and selected surgical therapy, but notes that a discussion of individualized risks and benefits is a standard component of the preoperative informed consent process.

Resource use

There are insufficient data to assess differences in resource requirements for surgical referral versus suboptimal PAP use.

Patient values and preferences

Because acceptability of surgical interventions varies and there is little harm in offering referral, based on their combined clinical experience the TF judged that most patients would generally be accepting of a discussion regarding referral but that the clinical utility of it may be more limited in patients who are partially PAP compliant as opposed to those who are completely untreated. The choice to pursue referral is expected to vary between patients based on personal values, beliefs, and expectations for recovery time or pain with surgery.

Surgical treatment as an initial therapy in patients with a major anatomical abnormality

Two RCTs[35, 37] and 16 observational studies[57, 78, 79, 96, 97, 114, 115, 136, 164, 172, 181, 192, 203, 205, 225, 244] investigated the use of surgery to improve one or more of the following outcomes: AHI/RDI, sleepiness, LSAT, sleep-related QOL, snoring, ODI, SBP, optimal PAP pressure, motor vehicle accidents, perioperative death, permanent dysphagia, and other serious persistent side-effects. For the RCTs,[35, 37] participants were randomized to surgery or no treatment. Participants were mostly male, 18-65 years of age, a mean BMI < 30 kg/m^2, moderate to severe OSA and tonsillar hypertrophy with velopharyngeal obstruction who were intolerant or unaccepting of CPAP therapy. The participants underwent palatal modification surgery and were followed for 4-7 months. For the observational studies[57, 78, 79, 96, 97, 114, 115, 136, 164, 172, 181, 192, 203, 205, 225, 244] comparisons between pretreatment and posttreatment were made. The studies included retrospective, and prospective cohort and case-control designs. Participants were mostly male, 21 to 67 years of age, with a mean BMI <35 kg/m^2, moderate to severe OSA, and a major anatomic abnormality. These abnormalities included tonsillar hypertrophy, class II occlusion (Angle classification), retrognathia, or maxillary hypoplasia. Participants underwent either tonsillectomy or craniofacial surgery and were followed for 3 months to 3 years. Several meta-analyses were performed to assess the efficacy of surgery as an initial therapy to treat OSA in adults. The meta-analyses are provided in the supplemental material, **Figure S53** through **Figure S68**. A Summary of Findings table is provided in the supplemental material, **Table S4**. A summary of the evidence for each outcome is provided below.

Critical Outcomes

The following outcomes were determined by the TF to be critical for evaluating the efficacy of surgery as an initial therapy: sleepiness, QOL, AHI/RDI, LSAT, ODI, snoring, perioperative death, and permanent dysphagia. Meta-analyses for AHI/RDI included all definitions as reported in the studies. None of the studies identified in our literature review reported data for QOL or perioperative death.

AHI/RDI: The AHI and RDI are commonly reported as measures of OSA severity. The efficacy of surgery as an initial therapy to reduce the AHI was evaluated using a meta-analysis of 2 RCTs.[35, 37] Participants were mostly male, 18-65 years of age, a mean BMI < 30 kg/m^2, moderate to severe OSA and tonsillar hypertrophy with velopharyngeal obstruction who were intolerant or unaccepting of CPAP therapy. The meta-analysis demonstrated a clinically significant reduction in AHI of -20.6 events/hr (95% CI: -39.0 to -2.1 events/hr) with surgery (see supplemental material, **Figure S53**). The quality of evidence was moderate due to imprecision associated with small sample size and a wide 95% confidence interval that crossed the CST.

The efficacy of surgery as an initial therapy to reduce the AHI was also evaluated using a meta-analysis of 7 observational studies.[57, 78, 96, 114, 115, 136, 164] Participants were mostly male, 21-67 years of age, with a mean BMI <35 kg/m^2 and moderate to severe OSA who had tonsillar hypertrophy or craniofacial obstruction.[57, 73, 78, 96, 97, 164, 172, 189, 205, 234, 256, 294-296] Most of the participants were offered but intolerant to CPAP therapy. Participants underwent palatal modification or maxillomandibular advancement (MMA) surgery and were followed for 3 months to 2 years. The meta-analysis demonstrated a clinically significant reduction in AHI of -37.6 events/hr (95% CI: -49.4 to -25.7 events/hr) resulting in an 84% reduction with surgery (see supplemental material, **Figure S54**). A subgroup analysis of 4 observational studies[57, 78, 114, 164] including participants with craniofacial abnormalities demonstrated a clinically significant reduction in AHI of -42.5 events/hr (95% CI: -49.4 to -35.5 events/hr) resulting in an 85% reduction with surgery (see supplemental material, **Figure S54**). A subgroup analysis of 3 observational studies including participants with tonsillar hypertrophy demonstrated a clinically significant reduction in AHI of -31.1 events/hr (95% CI: -48.7 to -13.4 events/hr) resulting in an 82% reduction with surgery (see supplemental material, **Figure S54**). The quality of evidence was moderate due to risk of bias associated with observational studies and large effect size.

The efficacy of surgery as an initial therapy to reduce the RDI was evaluated using an analysis of one RCT.[37] that reported on RDI. Participants were randomized to tonsillectomy with UPPP or no treatment and were followed for 3 months. Participants were mostly male, middle-aged, a BMI <34 kg/m^2, with moderate to severe OSA, and tonsillar hypertrophy, and intolerance to CPAP. The RCT[37] demonstrated a clinically significant reduction in the RDI of -6.9 events/hr (95% CI: -21.0 to 7.2 events/hr) (see supplemental material, **Figure S55**). The quality of evidence was moderate due to imprecision associated with small sample size.

The efficacy of surgery as an initial therapy to reduce the RDI was also evaluated using meta-analysis of 2 observational studies.[79, 225] The participants underwent palatal modification surgery or no treatment and were followed for 4-7 months. The meta-analysis demonstrated a clinically significant reduction in the RDI of -41.5 events/hr (95% CI: -65.6 to -17.4 events/hr), resulting in an 82% reduction with surgery (see supplemental material, **Figure S56)**. A subgroup analysis of one observational study[79] that included participants with craniofacial abnormalities demonstrated a clinically significant reduction in the RDI of -53.7 events/hr (95% CI: -64.1 to -43.3 events/hr) (see supplemental material, **Figure S56**). Another subgroup analysis of one observational study[213] that included participants with tonsillar hypertrophy demonstrated a clinically significant reduction in the RDI of -29.1 events/hr (95% CI: -40.4 to -17.8 events/hr) with surgery (see supplemental material, **Figure S56**). The quality of evidence was very low due to risk of bias associated with observational studies, and imprecision associated with small sample size.

SLEEPINESS: The efficacy of surgery as an initial therapy to reduce excessive sleepiness was evaluated using an analysis of one RCT[37] that reported on the ESS. Participants were mostly male, 18-65 years of age, with a mean BMI < 30 kg/m^2, moderate to severe OSA, tonsillar hypertrophy with velopharyngeal obstruction, and intolerance to CPAP. Participants underwent palatal modification surgery and were followed for a mean of 4.4±1 months. The analysis demonstrated a clinically significant reduction in sleepiness of -3.4 points (95% CI: -6.3 to -0.5 points) as measured by the ESS (see supplemental material, **Figure S57**). The quality of evidence was moderate due to imprecision associated with small sample size and a wide 95% confidence interval that crossed the CST.

The efficacy of surgery as an initial therapy to reduce excessive sleepiness was evaluated using a meta-analysis of 2 prospective cohort studies[115, 136] that reported on the ESS. Participants were mostly male, 21-67 years of age, a mean BMI < 30 kg/m^2, with moderate to severe OSA and tonsillar hypertrophy. Participants underwent tonsillectomy[115] or palatal modification surgery[136] and were followed for 3-6 months. The meta-analysis demonstrated a clinically significant reduction in sleepiness of -6.0 points (95% CI: -8.4 to -3.6 points) as measured by the ESS (see supplemental material, **Figure S58**). The quality of evidence was very low due to risk of bias associated with observational studies and imprecision associated with small sample size.

LOWEST OXYGEN SATURATION: The efficacy of surgery as an initial therapy to increase the LSAT was evaluated using an analysis of one RCT in participants with a major anatomical obstruction[37] that reported on the LSAT. Participants were mostly male, 18-65 years of age, a mean BMI < 30 kg/m^2, moderate to severe OSA, tonsillar hypertrophy with velopharyngeal obstruction, and intolerance to CPAP. Participants underwent palatal modification surgery and were followed for a mean of 4.4±1 months. Analysis demonstrated an increase in the LSAT that was not clinically significant with surgery (see supplemental material, **Figure S59**). The quality of evidence was very low due to risk of bias associated with observational studies, and imprecision associated with small sample size and a wide 95% confidence interval that crossed the CST.

The efficacy of surgery as an initial therapy to increase the LSAT was also evaluated using a meta-analysis of 4 observational studies in participants with either tonsillar hypertrophy or craniofacial abnormalities[57, 96, 164, 225] that reported on the LSAT. Participants were mostly male, 24-55 years of age, a mean BMI < 30 kg/m^2 with moderate to severe OSA and a major anatomical obstruction. Participants underwent MMA,[57, 164] palatal modification,[225] or UPPP [96] procedures and were followed for 3-6 months. The meta-analysis demonstrated a clinically significant increase in the LSAT of 9.1% (95% CI: 6.4 to 11.9%) that represents a 16% improvement with surgery (see supplemental material, **Figure S60**). The quality of evidence was low due to risk of bias associated with observational studies.

SNORING: The efficacy of surgery as an initial therapy to decrease snoring was evaluated using an analysis of one RCT[37] that reported on snoring. Participants were mostly male, 18-65 years of age, with a mean BMI < 30 kg/m^2, moderate to severe OSA, tonsillar hypertrophy with velopharyngeal obstruction, and intolerance to CPAP. Analysis demonstrated a clinically significant decrease in snoring of -3.7 points (95% CI: -5.3 to -2.1 points) as measured on a 10-point VAS with surgery (see supplemental materials, **Figure S61**). The quality of evidence was moderate due to imprecision associated with small sample size.

The efficacy of surgery as an initial surgery to decrease snoring was also evaluated using a meta-analysis of 2 observational studies[97, 205] that reported on snoring. Participants were mostly male, 29-60 years of age, with a mean BMI < 40 kg/m^2, moderate to severe OSA, and a major anatomical obstruction who failed CPAP therapy. Participants underwent palatal modification,[205] or UPPP[97] procedures and were followed for 6 months to 1 year. The meta-analysis demonstrated a clinically significant decrease in snoring of -5.5 points (95% CI: -5.9 to -5.1 points) as measured on a 10-point VAS after surgery (see supplemental material, **Figure S62**). The quality of evidence was low due to risk of bias associated with observational studies.

OXYGEN DESATURATION INDEX: The efficacy of surgery as an initial therapy to decrease the ODI was evaluated using an analysis of 1 retrospective study[244] that reported on the ODI. Participants were mostly male, mean age 42±11 years, mean BMI < 30 kg/m^2, with severe OSA and retroglossal obstruction. No use of CPAP was mentioned prior to surgery. Participants underwent coblation lingual tonsil removal and were followed for 6 months. Analysis demonstrated a clinically significant decrease in the ODI of -18.5 events/hr (95% CI: -26.8 to -10.2 events/hr) for a 56% reduction after surgery (see supplemental material, **Figure S63**). The quality of evidence was very low based on risk of bias associated with observational studies and imprecision associated with small sample size.

PERMANENT DYSPHAGIA: The risk of permanent dysphagia from upper airway surgery in patients with OSA and a major obstruction was evaluated using a meta-analysis of 5 observational studies.[115, 136, 192, 203, 244] The observational studies included retrospective, and prospective cohort designs. Participants were mostly male, 21-67 years of age, with a mean BMI < 35 kg/m^2 and moderate to severe OSA with an oropharyngeal obstruction. Participants underwent multilevel or hypopharyngeal surgery, tonsillectomy, or palatal modification procedures and were followed for 3 months to 4 years. The meta-analysis demonstrated a risk difference in permanent dysphagia before and after surgery that was not clinically significant (see supplemental material, **Figure S64**). The quality of evidence was very low due to risk of bias associated with observational studies and imprecision associated with a wide 95% confidence interval that crossed the CST.

Important Outcomes

The following outcomes were determined by the TF to be important for evaluating the efficacy of surgery as an initial therapy: BP and motor vehicle accidents. None of the studies identified in our literature review reported data for motor vehicle accidents.

BLOOD PRESSURE: The efficacy of surgery as an initial therapy to decrease mean SBP was evaluated using an analysis of 1 retrospective study.[205] Participants were mostly male, 29-51 years of age, with a mean BMI < 35 kg/m^2 and severe OSA with tonsillar hypertrophy who failed CPAP before beginning surgery. Participants underwent tonsillectomy and simultaneous palatoplasty procedures and were followed for 1 year. Analysis demonstrated a clinically significant decrease in SBP of -8.7 mm Hg (95% CI: -11 to -6 mm Hg) after surgery (see supplemental material, **Figure S65**). The quality of evidence was very low due to risk of bias associated with observational studies and imprecision associated with small sample size.

None of the articles included in this review reported on DBP.

Overall quality of evidence

The TF determined that the overall quality of evidence for the use of surgical treatments as an initial therapy was low based on the critical outcomes and downgrading of the evidence due to risk of bias associated with the observational studies, and imprecision within the RCTs (see supplemental material, **Table S4**).

Benefits vs harms

The potential benefits of upper airway surgery as an initial therapy include a reduction in sleepiness, snoring, SBP, AHI/RDI, and ODI, and an increase in LSAT. Benefits demonstrated in literature are limited to patients with a major anatomical obstruction considered appropriate for surgery by the treating surgeon and may not be representative of all OSA patients with similar anatomic findings. The potential harms of surgery include short-term discomfort that is expected during post-operative recovery and is discussed during the preoperative informed consent process. Additionally, potential persistent long-term side effects including taste alteration, mandibular paresthesia, and aspiration have been reported with some surgical procedures, but the incidence of these is low. An analysis of one observational study[203] demonstrated a risk difference in persistent taste alteration that was not clinically significant with surgery (see supplemental material, **Figure S66**). Meta-analysis of 2 observational studies[181, 203] demonstrated a clinically significant risk of persistent mandibular paresthesia of 0.17 (95% CI: 0.09 to 0.24) with surgery (see supplemental material, **Figure S67**). An analysis of 1 observational study[203] demonstrated a clinically significant risk in persistent aspiration of 0.05 (95% CI: -0.01 to 0.11) with surgery (see supplemental material, **Figure S68**). Given that even low surgical risks are elevated as compared to the minimal risk of initial PAP therapy, the balance of benefits to harms favors PAP therapy as initial treatment over discussion of referral for surgical evaluation. Nevertheless, the presence of major anatomical obstruction may tip the balance in favor of surgical referral discussion depending on a patient's upper airway medical history. Despite the low risk of surgical referral discussion, there is no harm in an initial trial of PAP therapy if other surgical indications are not present. Given that the intent of discussion of sleep surgery referral in this clinical scenario is consideration of upper airway surgery prior to any PAP trial and, based on their combined clinical experience, the TF judged that the potential benefits of surgical referral discussion in patients with major anatomical obstruction do not exceed the potential benefits of an initial PAP trial for OSA in the absence of other medical conditions affecting upper airway patency.

Resource use

There are insufficient data to assess differences in resource requirements for surgery versus PAP therapy or no treatment.

Patient values and preferences

Because acceptability of surgical interventions varies and there is little harm in offering referral, based on their combined clinical experience the TF judged that most patients would generally be accepting of a discussion regarding referral but that the clinical utility of it may be more limited in patients who are partially PAP compliant as opposed to those who are completely untreated. The choice to pursue referral is expected to vary between patients based on personal values, beliefs, and expectations for recovery time or pain with surgery.

DISCUSSION AND FUTURE DIRECTIONS

OSA is a common sleep disorder with significant physical, psychological, and social impacts. PAP is a highly efficacious treatment, but adherence to therapy is variable. Alternative surgical therapies to OSA have been available for decades but are sporadically employed for patients unaccepting or intolerant of PAP, creating a large, untreated population often lost to follow-up. Previous AASM surgical guidelines for OSA focused on evaluation of specific surgical therapies with recommendations that were broadly applied across diverse populations. Nonetheless, a growing body of evidence suggests that OSA is a heterogenous disease composed of many pathophysiologic mechanisms with varying presentations and responses to different treatments. The review of surgical literature presented here was designed to meet the needs of the sleep clinician considering a discussion of referral for surgical consultation for a patient found to be intolerant or unaccepting of PAP therapy or to have significant anatomic abnormalities. To that end, this review sought to best inform the sleep clinician's decision-making process regarding a discussion of referral for surgery by evaluating the overall impact of surgical inventions rather than stratifying by specific intervention. Patient-specific values and preferences may affect the decision for or against a variety of surgical options. It is ultimately the purview of the consulting surgeon to assess a patient's anatomy for potential surgical options, and to conduct a comprehensive discussion regarding potential risks and benefits so that the patient may make an informed decision. The conclusions in this review are limited to the available published data and by any inherent issues with underlying study designs. The systematic review performed by the task force identified several areas that merit further investigation to determine effects on patient outcomes and better inform clinical decision-making. Consistent limitations across the literature are outlined below.

Limitations

Several issues were noted across the studied literature, including.

1. *Variability in the procedural choice and technique.* A wide variety of surgical techniques were evaluated for therapeutic use in populations described using only basic demographic information. Anatomic information was rarely included to justify procedural selection. Many studies were isolated retrospective cohorts examining a unique modification of a standard surgical technique.
2. *Non-standardized reporting of outcomes.* A portion of the studies reviewed did not define internal success or failure criteria in assessed surgical outcomes, used non-standard criteria for evaluating outcomes of interest, or used non-validated internal metrics for measuring outcomes, preventing inclusion for meta-analysis.
3. *Small and heterogeneous study populations with inherent selection bias*. The surgical literature is mainly comprised of retrospective cohort studies without a control comparator. This is partly due to ethical considerations: randomized controlled trials with sham surgical interventions may cause significant harm without potential for benefit. Nonetheless, inclusion and exclusion criteria were often ill-defined or undocumented, limiting understanding of patient selection criteria and introducing potential selection biases.

Some literature limitations are due to the historical progression of alternative surgical therapies for OSA treatment. Until the mid-2000s, surgical therapy was primarily limited to uvulopalatopharyngoplasty, maxillomandibular advancement, and tracheostomy. These procedures continue to form the bulk of the available surgical literature and in the past were applied indiscriminately across heterogeneous populations prior to the development of current diagnostic and therapeutic options. The last 15 years have seen a proliferation of new therapeutic options enabled by advances in surgical technology including pharyngeal surgeries tailored to the individual patient's anatomy, transoral robotic surgery, and hypoglossal nerve stimulation. More recently, surgeons have begun to make a concerted effort to better understand what anatomic features best respond to selected interventions, using more complex diagnostic tools such as ultrasound, optical coherence tomography, cineMRI, and drug-induced sleep endoscopy.

Changing popularity of bariatric procedures over the last decade (from gastric banding as the most common procedure in 2010 to sleeve gastrectomy as the most common procedure in 2020) may have a different impact on OSA than observed in this analysis due to increased effectiveness on weight loss. In addition, weight loss occurs at different rates after bariatric surgery, and there was no standard timeframe for post-operative outcomes assessment. During the surgical consultation, the surgeon will discuss lifestyle changes necessary to be successful with bariatric surgery. Ultimately, patients will have to agree to major lifestyle changes to be successful with bariatric surgery and some are not ready for these changes.

Future research needs

Despite the promise of these emerging diagnostic and therapeutic alternatives, more studies are needed to better characterize OSA surgery response criteria and to ensure reproducibility. Clinical decision-making and guideline recommendations are expected to improve as research efforts expand into several key areas. In general, there is a need for standardized classification schema incorporating anatomic and non-anatomic data found to predict physician and patient-centered outcomes of interest. Research has historically focused on the AHI, but it does not always correlate well with patient-reported concerns such as daytime sleepiness, socially disruptive snoring, and co-morbid health risks. Validated metrics for quantifying patient-centered outcomes of interest (e.g., QOL) would benefit from development through focus group and survey studies evaluating patient treatment priorities. More research on surgical outcomes beyond standard polysomnography metrics are needed to better quantify changes in patient-centered outcomes as well as long-term cardiometabolic, neurocognitive, and mortality outcomes.

A relative paucity of literature evaluates the impact of surgical interventions on PAP setting requirements, adherence, and benefit. Surgery is historically considered to be a second-line therapy option for OSA after absolute failure of PAP, but there is a growing recognition of the role for surgery to improve PAP tolerance. Subpopulation research is needed to determine which surgical therapies can benefit initial or repeat PAP exposure, or even be curative of disease. Further work is also required to better evaluate patient preferences for PAP versus surgery as a first-line therapy, and to evaluate which patient characteristics and surgical interventions most impact future PAP adherence.

Lastly, the large effect size of bariatric surgery on OSA requires further exploration to better understand patient-centered outcomes of interest and phenotypes best responding to surgery. The optimal timing of post-operative re-evaluation for OSA is unknown, and there is a need for studies exploring the impact of bariatric surgery on OSA in patients with a body-mass index less than 35 mg/kg^2 given the observed benefit seen in patients with other comorbidities, such as diabetes.

Disclosures

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