

An American Sleep Disorders Association Review

The Efficacy of Surgical Modifications of the Upper Airway in Adults With Obstructive Sleep Apnea Syndrome

*Aaron E. Sher, †Kenneth B. Schechtman and ‡Jay F. Piccirillo

**Division of Otolaryngology-Head and Neck Surgery, Albany Medical College and Capital Region Sleep Wake Disorders Center of Albany Medical Center and St. Peter's Hospital, Albany, New York, U.S.A.; and*

†Division of Biostatistics and ‡Department of Otolaryngology-Head and Neck Surgery, Washington University School of Medicine, St. Louis, Missouri, U.S.A.

Summary: This paper, which has been reviewed and approved by the Board of Directors of the American Sleep Disorders Association, provides the background for the Standards of Practice Committee's parameters for the practice of sleep medicine in North America. The intent of this paper is to provide an overview of the surgical treatment of obstructive sleep apnea syndrome, to provide the basis for the American Sleep Disorders Association's practice parameters on this subject and to share our findings of metaanalysis of previously published studies regarding uvulopalatopharyngoplasty. We searched MEDLINE from January 1966 through April 1993, with an update in February 1995, to provide a review of the application of surgical modifications of the upper airway to treat adults with obstructive sleep apnea syndrome. Operations to treat obstructive sleep apnea syndrome include nasal septal reconstruction; uvulopalatopharyngoplasty; uvulopalatopharyngoglossoplasty; laser midline glossectomy; lingualplasty; inferior sagittal mandibular osteotomy and genioglossal advancement, with hyoid myotomy and suspension (the entire process is referred to as GAHM); maxillomandibular osteotomy and advancement, and tracheotomy. Papers included in metaanalysis provided preoperative and postoperative polysomnographic data on at least nine patients treated with uvulopalatopharyngoplasty for their obstructive sleep apnea. Analysis of the uvulopalatopharyngoplasty papers revealed that this procedure is, at best, effective in treating less than 50% of patients with obstructive sleep apnea syndrome. The site of pharyngeal narrowing or collapse, although identified by different and unvalidated methods, has a marked effect on the probability of success of uvulopalatopharyngoplasty. Patients who achieve a favorable response with uvulopalatopharyngoplasty tend to have less severe obstructive sleep apnea than those who do not. For patients who demonstrate retrolingual narrowing or collapse, other surgical modifications have been described, such as lingualplasty, GAHM, and maxillomandibular osteotomy and advancement. The studies to support the use of the surgical treatment of obstructive sleep apnea syndrome contain biases related to small sample size, limited follow-up and patient selection. **Key Words:** Sleep apnea syndromes, surgery—Meta-analysis—Pharynx—Uvula—Tonsillectomy—Airway—Polysomnography—Practice guidelines—Tracheotomy—Uvulopalatopharyngoplasty.

1.0 INTRODUCTION AND BACKGROUND

Sleep-disordered breathing, often referred to as sleep apnea or sleep apnea syndrome, is characterized by repeated episodes of apnea and hypopnea during sleep. Apnea, which refers to a cessation of airflow for 10 or more seconds, is termed central when no respiratory effort is present. If respiratory effort persists despite cessation of airflow, the apnea is obstructive.

Hypopneas are similarly classified and differ from apneas in that during a hypopneic event, airflow is diminished but not absent (1). Obstructive sleep apnea syndrome (OSAS) is defined by the presence of at least a minimum number of obstructive apneas and hypopneas per hour of sleep and the presence of mental or physical effects (or both) that result from the respiratory disturbances (2). Different authors use different minimal criteria for the number of apneas or hypopneas per hour that define the syndrome. Among these criteria have been five apneas per hour, 10 apneas per hour and a combination of 10 apneas or hy-

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Address correspondence and reprint requests to Aaron E. Sher, M.D., 980 Western Avenue, Albany, NY 12203 U.S.A.

popneas per hour, the latter definition being commonly used at this time.

The prevalence of sleep-disordered breathing, defined as an apnea-hypopnea index (AHI) of at least 5, is estimated to be 24% of adult males and 9% of adult females; the prevalence of OSAS is 4% of males and 2% of females in a cohort of employed 30- to 60-year-old individuals (3). Estimates for elderly males range from 28% to 67% and for elderly females from 20% to 54% (4-8). The significance of these numbers in the elderly and the frequency with which the apnea occurs without pathologic significance have yet to be determined. Current projections of the prevalence of OSAS in the United States range from 7 million to 18 million people (9).

Potential health consequences of OSAS are cardiovascular disease, including hypertension, myocardial infarction, and stroke (10-15); neuropsychiatric problems, such as depression and cognitive dysfunction, that are related to excessive daytime sleepiness (EDS) and injury; secondary to accidents caused by the EDS (16). Increased mortality has also been reported (17,18).

1.1 Anatomic abnormalities in adults with OSAS

Only three in 200 adult patients with OSAS have a specific space-occupying lesion that results in sleep-related upper-airway obstruction. In such cases, surgical extirpation is corrective (19,20). In the other 98.5% of adult patients with OSAS, no such lesion is identifiable and apnea results from a disproportionate anatomy of the upper airway and its supporting structures (20). Nasal obstruction can result from bony and cartilaginous anatomic abnormalities or from reactive soft-tissue changes. The dimensions and spatial relationships of the pharynx are determined by i) soft tissues, such as tonsils, that directly abut the air column; ii) the underlying foundation of muscles that comprise the pharynx and whose orientation directly affects the dimensions and configuration of the pharyngeal lumen; and iii) the location of the bony insertions and origins of these muscles in the bones of the craniofacial skeleton and, therefore, the specific craniofacial-skeletal attributes of the patient (19). Analysis of lateral cephalograms (standardized lateral radiographic projections of the head and neck) indicate that, when compared to normal subjects, patients with OSAS have a variety of craniofacial-skeletal deviations (21). Data derived from studies of the pharynx using awake endoscopy, awake endoscopy with Müller maneuver, asleep (drug-induced) endoscopy, asleep (natural and drug-induced) endoscopy with continuous positive airway pressure (CPAP), asleep

TABLE 1. *Classification of regions of pharyngeal narrowing or collapse or presumed regions vulnerable to narrowing or collapse*

Type	Regions of pharynx involved
I	Retropalatal
II	Retropalatal and retrolingual
III	Retrolingual

fluoroscopy, computed tomographic (CT) scan, and manometry suggest that different patients with OSAS have different patterns of static narrowing of the pharynx, resulting in different patterns of dynamic narrowing or collapse of the pharynx (21,22). These observations, in combination with analyses of which patterns of pharyngeal obstruction tend to result in surgical success and failure, have led to the pragmatic conclusion that the pharynx can be functionally divided into two portions: the retropalatal pharynx (the region of the pharynx posterior to the soft palate) and the retrolingual pharynx (the region of the pharynx posterior to the vertical portion of the tongue). The division of the pharynx into these entities does not represent a formal anatomic classification but, rather, a descriptive paradigm that appears to have significance in terms of functional and, therefore, surgical considerations (23). On this basis, patterns of pharyngeal obstruction, narrowing, or collapse have been classified in the following manner: Type I—narrowing or collapse in retropalatal region only, Type II—narrowing or collapse in both retropalatal and retrolingual regions, and Type III—narrowing or collapse in retrolingual region only (Table 1) (23).

1.2 Nonsurgical treatment modalities: behavior modification, drug therapy, and mechanical devices

Behavior modification includes alteration of sleep position, avoidance of alcohol and sedative medication, and weight-reduction programs. Avoidance of alcohol and sedative medication prevents exacerbation of existing OSAS but does not treat the syndrome. Weight reduction is potentially therapeutic, but permanent loss of significant excess body weight by behavioral means alone is rarely successful (24,25). Drug therapy for OSAS is of limited clinical value (26,27). Mechanical devices that affect pharyngeal mechanics by altering the relative position of the upper and lower jaws and tongue may be effective in diminishing snoring and apnea in some patients (28). Nasal CPAP, a mechanical device that treats OSAS by the application of positive air pressure to the pharynx via the nose, is regarded as the mainstay of ther-

apy, but variable patient compliance rates appear to be a problem (29).

1.3 Upper-airway surgical approaches

Upper-airway surgical approaches for the treatment of OSAS fall into three categories: i) classic procedures that directly enlarge the upper airway, ii) specialized procedures that directly enlarge the upper airway, and iii) tracheotomy for control of OSAS by means of bypassing the pharyngeal portion of the upper airway.

1.3.1 Classic surgical techniques

Classic surgical techniques (i.e. nasal-septal reconstruction, cauterization, and outfracture of turbinates) have been employed to alter the soft tissue and skeleton of the nose, and classic pharyngeal procedures such as tonsillectomy have been used to enlarge the pharyngeal space. However, in light of the frequent failure of these procedures to correct OSAS, new surgical approaches were developed to deal with the disproportionate pharyngeal anatomy.

1.3.2 Specialized surgical techniques

Some specialized procedures modify primarily soft-tissue elements, while others modify skeletal anatomy. Each procedure tends to focus on either the retropalatal or retrolingual portion of the pharyngeal airway and may be applied individually, synchronously with other procedures, or sequentially with other procedures, depending on the nature of the anatomic problem at hand. These procedures include the following operations: a) Uvulopalatopharyngoplasty (UPPP) is a procedure that enlarges the retropalatal airway through excision of the tonsils, if present; trimming and reorienting of the posterior and anterior tonsillar pillars, and excision of the uvula and posterior portion of the palate (Fig. 1) (30). b) Uvulopalatopharyngoglossoplasty (UPPGP) is an operation that incorporates a modified UPPP with limited resection of the tongue base (31,32). c) Laser midline glossectomy (LMG) and lingualplasty are two procedures that create an enlarged retrolingual airway by laser extirpation of a 2.5 cm × 5 cm midline, rectangular strip of the posterior half of the tongue. Laser lingual tonsillectomy, reduction of the aryepiglottic folds, and partial epiglottectomy are performed in selected patients. Lingualplasty differs from LMG in that additional tongue tissue is extirpated posteriorly and laterally to that portion excised in LMG, and lingualplasty reportedly results in a higher response rate

(33,34). d) Inferior sagittal mandibular osteotomy and genioglossal advancement with hyoid myotomy and suspension (ISO, referred to also as GAHM) represents a procedure consisting of two parts: i) inferior sagittal mandibular osteotomy and genioglossal advancement, and ii) hyoid myotomy and suspension. The two components of the procedure create an enlarged retrolingual airway. The combined procedure will be hereafter referred to as GAHM. In GAHM, the genio tubercle of the mandible, which serves as the anterior attachment of the tongue, is advanced by means of a limited mandibular osteotomy. In the original version of GAHM, the hyoid bone was advanced and suspended from the mandible by a fascial strip. Newer modifications involve stabilization of the hyoid bone anteriorly and inferiorly by attachment to the thyroid cartilage. There is no change in dental occlusion (Fig. 2) (35). e) Maxillomandibular osteotomy and advancement (MMO) provides maximal enlargement of the retrolingual airway and some enlargement of the retropalatal airway. The maxilla and mandible are advanced simultaneously by means of Le Fort I maxillary and sagittal-split mandibular osteotomies. Moving the maxilla forward permits greater forward motion of the mandible because it allows for maintenance of dental occlusion, i.e. both the upper and the lower teeth are moved in a coordinated fashion. The net result is that the tongue is advanced to a greater degree than with GAHM alone. The details of the procedure depend on the patient's natural occlusion pattern (Fig. 3) (36,37).

1.3.3 Tracheotomy

Tracheotomy refers to the surgical procedure that creates a percutaneous opening into the trachea. The diameter of the stoma, or tracheostomy, is usually stented and maintained by inserting in it a rigid or semirigid hollow tube that extends to the body surface. The patient breathes through the tube when the external end is unplugged. Since the tracheostoma enters the airway distal to the pharynx and larynx, it bypasses the portion of the airway that narrows or collapses in OSAS, i.e. the pharynx. This procedure relieves the patient of symptoms resulting from OSAS as long as the patient sleeps with the tracheostomy tube unplugged. When the patient is awake, the external end of the tube is plugged, redirecting the flow of air through the nose or mouth, pharynx, and larynx. The tracheostomy tube is of sufficiently small diameter that, when plugged, it permits air entering the trachea from above through the pharynx and larynx to pass around the tube into the distal trachea and lungs. The increased resistance to airflow created by the presence of the plugged tube occupy-

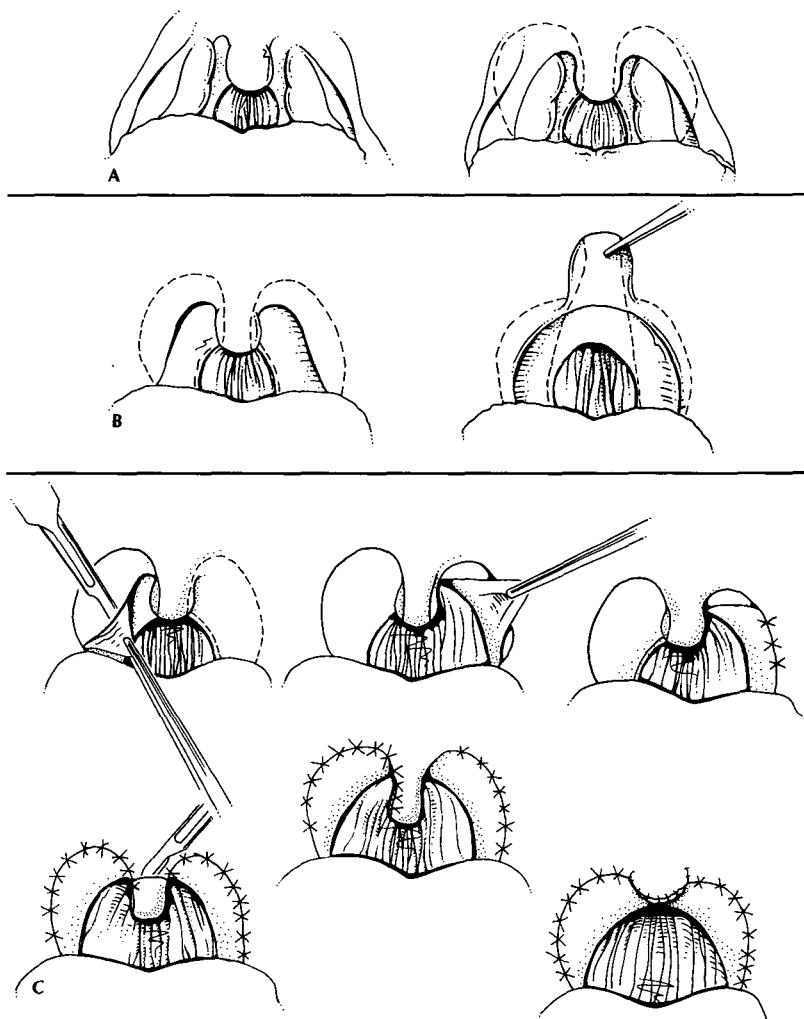


FIG. 1. Uvulopalatopharyngoplasty (UPPP). Tonsillectomy is performed if it has not been done previously. If it has been done previously, the mucosa of the tonsillar fossae is excised. An incision is made in the soft palate, several millimeters lateral to the medial margin of the glossopalatal arch, extending from the inferior pole of the tonsillar fossa to the root of the uvula, then to its tip, then up the pharyngeal side of the uvula, continuing along the pharyngopalatal arch to the inferior pole of the tonsillar fossa. A. UPPP incisions in a patient who has not had prior tonsillectomy. B. UPPP incisions in a patient who has had prior tonsillectomy. C. Completion of UPPP in a patient who had prior tonsillectomy. Reprinted with permission from *Current Science*, *Rapid Science*, and *Mosby—Year Book* (30).

ing a portion of the tracheal lumen can be decreased by using a tube that has ventilating holes at the distal end through which the air can flow.

2.0 PURPOSE

The goal of this study is to review the literature covering the surgical treatment of OSAS and to determine the efficacy of the various operations.

3.0 METHODS

3.1 MEDLINE search and review of papers

This review was commissioned by the Standards of Practice Committee of the American Sleep Disorders

Association. A search of the published medical literature was performed using the MEDLINE bibliographic database, covering January 1966 through April 1993, with an update in February 1995. Medical subject headings included sleep apnea syndromes, snoring, and surgery. All articles written in English that included only adult subjects (age greater than 18 years) and were published between the dates listed above were retrieved. Reviews, editorials, and letters were excluded from our evaluation, with 175 articles representing the clinical studies remaining: 87 on UPPP; 32 on tracheotomy; 31 on MMO; 13 on bariatric operations; eight on nasal operations, tonsil operations, or both operations; two on tongue surgery and two on UPPGP. However, because this paper is limited to operations on the upper airway, bariatric

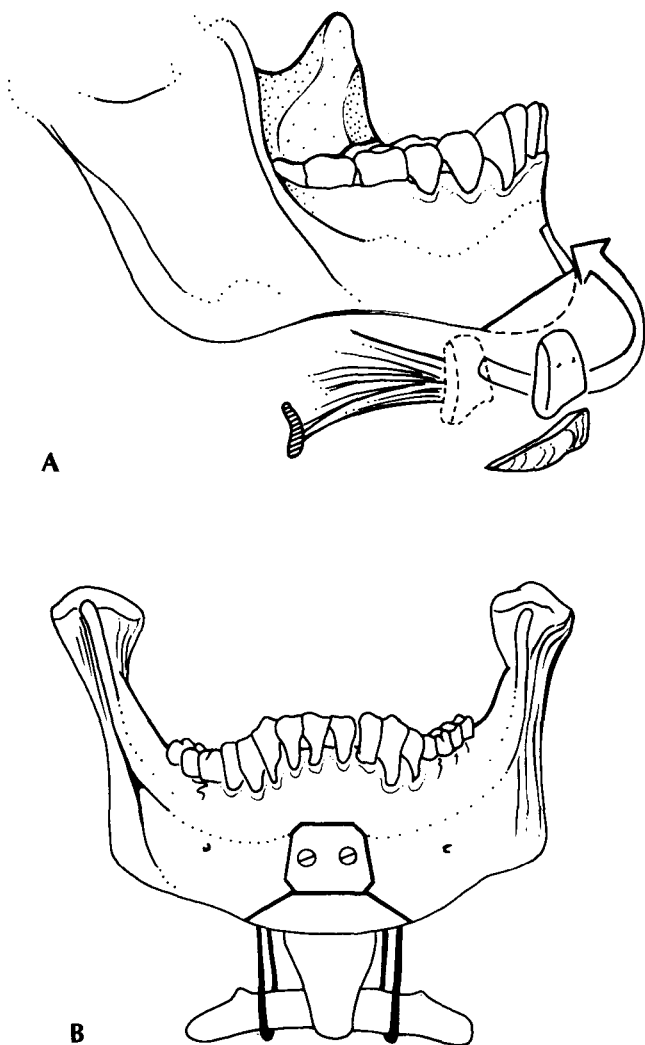


FIG. 2. Genioglossal advancement with hyoid myotomy and suspension. Following limited mandibular osteotomy, which isolates the genio tubercle, the released segment of bone is drawn anteriorly and fixed into a position anterior to the mandible. Hyoid myotomy frees the hyoid from its inferior muscle attachments in the neck. Hyoid suspension is accomplished by passing a strip of fascia lata around the body of the hyoid and fixing it to the anterior mandible. (Note: a different technique for hyoid suspension has recently been introduced.) A. Diagrammatic representation of the anterior movement of the freed segment of mandible with the attached genioglossus to its new position anterior to the mandible. B. The freed segment of mandible is fixed in position anterior to the mandible. The hyoid is freed from its inferior attachments in the neck and suspended from the anterior mandible by strips of fascia lata. Reprinted with permission from *Current Science*, *Rapid Science*, and *Mosby—Year Book* (37).

operations were not reviewed. The clinical studies were then grouped according to the type of surgical procedure described. Articles that described multiple procedures were classified according to the procedure performed most frequently. These surgical procedures included tracheotomy, tonsillectomy, UPPP, UPPGP, septoplasty, lingualplasty, MMO, and GAHM.

From this group of articles, papers were excluded if: i) the patient population was less than nine (the

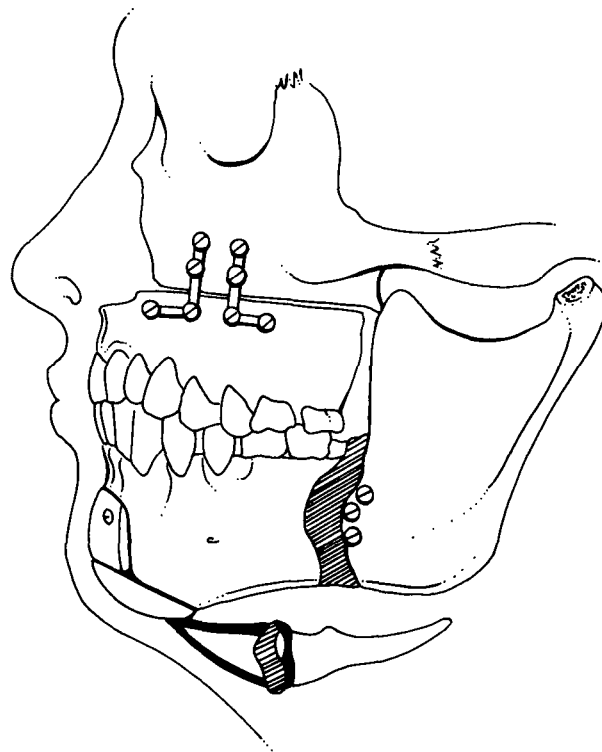


FIG. 3. Maxillomandibular advancement. Mandibular and maxillary osteotomies are performed, and both mandible and maxilla are advanced. Genioglossal advancement with hyoid myotomy and suspension have also been performed. Reprinted with permission from *Current Science*, *Rapid Science*, and *Mosby—Year Book* (37).

original protocol required a minimum of 10 patients in all qualifying articles, but the protocol was modified to accommodate a small number of papers that met all qualifications for inclusion but reported data on only nine patients); ii) a clear and unambiguous outcome measure (i.e. postoperative sleep study) was not reported; or iii) the patients had already been described in another included study. These qualifications reduced the number of articles from 175 to 109. The remaining articles were then reviewed in detail by two of us (A.E.S. and K.B.S.). All quantitative information collected during this detailed review (K.B.S.) was independently confirmed by one of us (A.E.S.). Papers excluded at this stage included those that contained information about snorers who may not have had sleep apnea and those studies lacking appropriate baseline data, i.e. apnea index (AI) or respiratory disturbance index (RDI). Sixteen papers were excluded because it was clear from the paper itself, or following contact with the author, that the paper reported results that were discussed in a second manuscript contained in this report. This process resulted in the selection of 54 articles for inclusion in our study.

TABLE 2. Definitions of UPPP groups

Group	Included preoperative data	Number of patients per study	Included postoperative data
1	Mean AI and RDI	≥ 9	Mean AI and RDI
2	Mean AI and RDI	≥ 9	Sufficient information to determine response rate
3	Mean AI or RDI and raw AI or RDI	≥ 9	Raw AI and RDI

3.2 Definition of measures

A complete description and definition of the terms referred to in this paper are included in Appendix A.

3.3 Description of selected papers

Papers that met the criteria for selection and whose focus was nasal (38) and tongue operations (33,34) will be reviewed, as will papers on tracheotomy (39–41). Because we had few papers in each of these three categories, data will be presented, but no attempt will be made to perform statistical analysis other than that already performed by the authors. No papers on tonsillectomy met the selection criteria. Reports that met the criteria for selection and whose focus is mandibular and maxillomandibular operations will be reviewed (35–37,42). The papers that met criteria for inclusion were from four investigative groups. The data in nine papers by Riley et al. were comprehensively analyzed in a publication by the same authors (37). That summary publication, including the cumulative data, was used for this report. The results of the 37 papers (43–79) that evaluate UPPP operations and that met the criteria for selection will be presented and analyzed statistically. Two papers on UPPGP will be reviewed without statistical analysis (31,32).

3.4 Description of analysis of UPPP papers

The 37 UPPP papers fall into three largely overlapping categories. The three groups are treated separately because they define three distinct categories of data analysis. The requirements for being included in each of the three groups are highlighted in Table 2. Group 1 papers contain requisite *mean* data (at least *mean* preoperative and postoperative AI or RDI) for a minimum of nine patients with OSAS. As a subgroup of Group 1 papers, Group 2 papers also contain the *mean* data and, in addition, provide sufficient postoperative information to determine the response rate of the surgical procedure in terms of specific criteria of success, i.e. achieving at least a 50% decrease in AI or at least a 50% decrease in RDI. Group 3 papers also met the requirements for inclu-

sion in Group 1 and Group 2 and, in addition, include *raw* data on at least preoperative and postoperative AI or RDI.

3.4.1 Location of pharyngeal narrowing or collapse

A goal of this review was to evaluate all available information about the association between the site of pharyngeal narrowing or collapse and the success of UPPP. The relevance of this issue extends beyond implications of patient selection for UPPP and may help direct future research into surgical techniques for the treatment of OSAS. We focused primarily on the Group 3 studies, i.e. those that presented raw data and dichotomously categorized each patient as having either retropalatal airway narrowing or collapse (Type I); or having retrolingual narrowing or collapse with or without retropalatal airway narrowing or collapse (Type II and Type III, respectively). The major focus of functional pharyngeal narrowing or collapse (i.e. retropalatal versus retrolingual) was determined by the following methods: fiberoptic awake endoscopy with or without Müller maneuver (45,54,61,69), asleep endoscopy with CPAP (22), lateral cephalometric radiography (61,65,69), airway manometry (53,63), and pharyngeal CT scan (66).

3.4.2 Statistical methods

Data were analyzed using SAS (80) as implemented on the SUN computer system of the Division of Biostatistics at Washington University, St. Louis, MO. Continuous variables are expressed as mean \pm standard deviation, with standard deviations being presented only when using raw data from Group 3 papers. A p-value of less than 0.05 determined statistical significance.

Metanalytic techniques described by Rosenthal (81) were used to combine p-values from different studies into a single p-value that assessed overall significance. When precise p-values were not presented (in the papers we reviewed), we computed them using either the raw data or means and standard deviations presented by the authors. The metaanalyses were

weighted by the sample size in the individual papers. Note that the selected approach to metaanalysis has the advantage of being applicable even when standard deviations and standard errors are missing, common occurrences in several papers. The selected approach also permitted a single metaanalysis of papers with body weight and body mass index data, a pooling that would not be possible using other methods.

When aggregate data from different papers were related to one another (Group 1 papers), Pearson's correlation coefficients, weighted by the sample size in the paper, were employed. However, because the raw data on percentage change in AI and RDI were skewed, Spearman's correlation coefficients, which are based on the ranks of the data, were used in Group 3 papers. Two-tailed paired Student's *t* tests compared baseline characteristics of responders and nonresponders. However, because percentage change data were highly skewed, Wilcoxon's rank-sum test was used in comparing change data in patients with retropalatal and retrolingual narrowing or collapse. Mean percentage changes in AI and RDI are presented after excluding outliers, defined as increases in either of these measures of more than 100%.

4.0 RESULTS

4.1 Nasal operations

The effects of nasal operations were reviewed in one paper that evaluated 20 adults with sleep apnea (38). Operations included septoplasty, turbinectomy, polypectomy, or a combination of these procedures. Cephalometric measurements were obtained. In 14 of the patients, nasal resistance was objectively measured in conjunction with polysomnography (PSG) preoperatively and 2 to 3 months postoperatively. Nasal resistance decreased significantly after the operation, from 3.0 ± 0.1 cm H₂O·L⁻¹·s⁻¹ preoperatively to 1.7 ± 0.2 cm H₂O·L⁻¹·s⁻¹ postoperatively (*p* = 0.0001). There were no significant differences between baseline and postoperative values in RDI (39.8

± 6.1 and 36.8 ± 5.9 , respectively), total apnea time, and the severity of nocturnal oxygen desaturations. Total sleep time increased significantly after surgery, but the sleep efficiency remained unchanged. The composition of the total sleep time within the different sleep stages changed significantly, with an increase in rapid eye movement (REM) sleep time from $11.5 \pm 1.3\%$ to $14.0 \pm 1.2\%$ (*p* < 0.05). Other changes in sleep-stage distribution did not occur. Sleep fragmentation did not change. Body weight remained relatively unchanged (101.6 ± 5.2 kg vs. 102.7 ± 5.5 kg). There was no significant relationship between the changes in the RDI and the baseline nasal-resistance values (*r* = 0.1, *p* = 0.3).

The RDI returned to normal (less than 10) in four patients (20%). These patients differed from all of the other patients in that they had normal mandibular plane-hyoid distance and normal posterior-airway space on cephalometry. This group of successfully treated patients also had mild apnea (mean preoperative RDI of 16.7 ± 4.6 as compared to 39.8 ± 6.1 for the entire group).

4.2 UPPP operations

4.2.1 Group 1 papers

These 37 papers reported mean baseline and mean postoperative data on 992 subjects who underwent UPPP for the treatment of OSAS. Twenty-two papers (*n* = 705) reported information about gender (90.5% male), and 25 papers (*n* = 748) reported age, with a mean age of 48.1 years. Table 3 summarizes baseline and percentage change data. Standard metaanalytic techniques for combining *p*-values between studies after weighting for sample size found that the very large changes in AI, RDI, and minimum oxygen saturation (Min O₂ Sat) were all highly significant (*p* < 0.0001).

Although the number of papers with post-UPPP data on the change in percentage of REM sleep, body weight, and BMI was limited, results indicated that

TABLE 3. Mean data for Group 1 papers (*n* = 992)

Variable	Baseline values		No. of papers	Total n	Percentage change		No. of papers	Total n
	Weighted average	Range			Weighted average %	Range %		
Age (years)	48.1	(38.5, 54.4)	25	748				
Male (%)	90.5	(58.8, 100)	22	705				
Apnea index	45.2	(27.0, 71.3)	21	570	-55.2	(-84.3, -17.2)	20	520
Respiratory disturbance index	60.0	(25.8, 82.1)	19	529	-38.2	(-72.1, 11.8)	18	497
Minimum O ₂ saturation	65.6	(40.9, 85.7)	23	626	17.9	(0.0, 49.9)	23	626
REM sleep (%)	11.8	(6.5, 17.1)	8	280	12.3	(-7.7, 55.8)	6	232
Weight (lb)	234	(182, 275)	16	538	-2.9	(-4.9, 0.3)	5	143
Body mass index (kg/m ²)	32.7	(29.5, 37.0)	12	365	-1.7	(-2.7, 0.1)	5	116

UPPP was associated with a 12.3% increase in REM sleep (six papers, $n = 232$), a 2.9% decrease in body weight (five papers, $n = 143$), and a 1.7% decrease in BMI (five papers, $n = 116$). Metanalysis showed that the increase in REM sleep was significant ($p = 0.002$), reflecting a weighted average of a small decrease in REM sleep in three studies, combined with a substantial and significant increase in three other studies.

The decrease in BMI (treated as raw data rather than percentage change) was significant ($p = 0.005$). This metanalysis combined p -values from the five studies that had pre-UPPP and post-UPPP BMI data and the four papers that had preoperative and postoperative data on body weight but not on BMI.

The Pearson correlation coefficient between mean baseline AI and percentage change in AI was computed after weighting for the sample size in each paper. Among the 20 Group 1 papers that provided the necessary data, the correlation was 0.502 ($p = 0.024$), suggesting that a high baseline AI was associated with a lower percentage decrease in this parameter. The correlation between baseline RDI and the percentage change in RDI (18 papers) was 0.106 ($p = 0.675$). Correlations associated with mean weight, BMI, and percentage of REM sleep are not presented because of the small number of papers with such data available.

4.2.2 Group 2 papers

The Group 2 papers provide adequate information to permit the calculation of the rate of response in groups of patients who were treated with UPPP (Tables 4 and 5). Of these 29 papers ($n = 819$), 14 defined response as a 50% decrease in AI [response rate, 229 of 352 (65.1%)], 16 defined response as a 50% drop in RDI [response rate, 197 of 375 (52.5%)], and five defined responses as some other definition [response rate, 127 of 225 (56.4%)]. These numbers add up to more than 29 papers because six papers permitted response to be defined in terms of both AI and RDI (Tables 4 and 5).

For each paper in Tables 4 and 5, p -values comparing parameter values in responders and nonresponders were computed. Metanalyses comparing p -values and weighted by sample size found no significant differences between responders and nonresponders in terms of age, AI, Min O₂ Sat, or body weight.

4.2.3 Group 3 papers

As a subset of the Group 1 and Group 2 papers, Group 3 includes the 17 papers that contained raw

data. Group 3 also contains two additional papers that were not in either Group 1 or Group 2. These two papers contain raw data on a subset of a larger group of patients discussed in detail, but without raw data, in two different papers assigned to Group 1. For this reason, the two papers containing raw data were included in Group 3 but not in Group 1. The 19 Group 3 papers contained raw data on 345 subjects.

Table 6 summarizes Group 3 baseline raw data according to whether subjects were responders or nonresponders. The results of unpaired two-tailed Student's t tests comparing responders and nonresponders are also presented. When defined as a 50% drop in AI, the response rate was 65.8% (129/196). There were no statistically significant differences between responders and nonresponders. However, trends suggest that nonresponders had a higher baseline AI (51.7 ± 32.5) than did responders (43.1 ± 27.9) ($p = 0.055$) and that nonresponders had a lower baseline body weight (217 ± 53.4 lb) than did responders (240 ± 69.4 lb) ($p = 0.094$). When defined as a 50% drop in RDI, the response rate was 52.8% (114/216). Using this definition of response, baseline RDI was significantly higher in the nonresponders (60.5 ± 25.0) than in the responders (52.1 ± 30.8) ($p = 0.028$). When response was defined as a 50% drop in AI or RDI, with consequent achievement of an AI of less than 10 or an RDI of less than 20, the response rate was 40.7% (137/337). Nonresponders had a higher baseline AI (56.6 ± 30.5) than did responders (31.2 ± 23.3) ($p = 0.0001$) and a higher baseline RDI (65.7 ± 26.7) than did responders (43.1 ± 26.3) ($p = 0.0001$). Nonresponders had a lower Min O₂ Sat than did responders (60.0 ± 18.2 vs. 66.9 ± 19.0 , respectively) ($p = 0.030$). No other differences between responders and nonresponders achieved statistical significance.

Spearman's rank order of correlation coefficients relating the baseline parameters contained in Table 6 with the actual percentage change in AI and RDI were computed. Subjects with high baseline AIs tended to have smaller percentage reductions in AI ($n = 196$, correlation = -0.202 , $p = 0.005$) and, exhibiting relationships that were in the opposite direction, greater reductions in RDI ($n = 80$, correlation = 0.249 , $p = 0.026$). No other variable exhibited even a trend toward a significant correlation with changes in AI or RDI ($p > 0.1$ in all cases). Since sample sizes for these correlations were substantial (ranging from 53 to 216) for all variables except baseline percentage of REM sleep, confidence bounds on correlation coefficients are narrow. With the exception of AI, and with REM data being too sparse to reach conclusions, none of the baseline parameters contained in Table 6 provides useful predictive infor-

TABLE 4. Baseline preoperative characteristics of responders (R) and nonresponders (NR): response rate determined by apnea index (AI)

First author	Response rate % defined as a 50% decrease in AI	Age (years)		Apnea index		Respiratory disturbance index		Minimum oxygen saturation		Percentage of REM sleep		Weight (lb)		Body mass index (kg/m ²)	
		R	NR	R	NR	R	NR	R	NR	R	NR	R	NR	R	NR
Anand (43)	28/45 = 62.2	—	—	58.2	42.8	—	—	64.5	69.5	—	—	—	—	—	—
deBerry-Borowiecki (45)	14/30 = 46.7	52.3	50.1	42.6	69.6	—	—	—	—	—	—	—	—	—	—
Burgess (46)	9/10 = 90.0	43.3	42.0	32.6	9.4	43.0	17.5	76.0	60.6	—	—	201	248	30.3	31.0
Caldarelli (48)	11/22 = 50.0	47.3	56.0	84.2	55.8	—	—	—	—	—	—	250	213	—	—
Fujita (50)	33/66 = 50.0	—	—	58.3	60.2	—	—	46.3	35.1	9.8	11.6	—	—	—	—
Kimmelman (56)	12/20 = 60.0	49.7	51.0	38.3	50.1	—	—	—	—	—	—	238	207	35.2	30.1
Lusk (60)	21/27 = 77.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Macaluso (61)	28/33 = 84.8	—	—	30.4	21.9	47.1	57.5	65.3	62.2	—	—	244	279	—	—
Metes (63)	7/11 = 63.6	46.3	38.0	49.6	38.7	72.6	54.5	72.7	64.2	—	—	—	—	29.9	30.2
Philip-Joet (65)	11/14 = 78.6	56.6	46.7	41.7	37.7	—	—	48.4	59.3	—	—	195	177	30.4	28.0
Polo (66)	9/11 = 81.8	—	—	51.4	78.0	—	—	—	—	—	—	—	—	—	—
Saunders (71)	5/9 = 55.6	—	—	28.2	39.5	—	—	—	—	—	—	—	—	—	—
Sher (74)	26/30 = 86.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Wetmore (77)	15/24 = 62.5	—	—	41.6	42.7	66.8	72.4	59.3	65.6	—	—	—	—	—	—
Means	229/352 = 65.1	49.8	49.9	47.9	52.3	54.5	61.5	59.3	52.1	9.8	11.6	231	220	31.8	29.8
		n = 64	n = 44	n = 182	n = 114	n = 59	n = 20	n = 131	n = 73	n = 33	n = 33	n = 71	n = 28	n = 39	n = 17

Because we have excluded patients with baseline AI < 5 where raw data made this exclusion possible, some small differences exist between our results and those in some published manuscripts.

TABLE 5. Characteristics of responders (R) and nonresponders (NR): response rate determined by respiratory disturbance index (RDI)

First author	Response rate% defined as a 50% decrease in RDI	Age (years)		Apnea index		Respiratory disturbance index		Minimum oxygen saturation		Percentage of REM sleep		Weight (lb)		Body mass index (kg/m ²)	
		R	NR	R	NR	R	NR	R	NR	R	NR	R	NR	R	NR
Launois (22)	8/18 = 44.4	—	—	—	—	87.0	73.1	—	—	—	—	—	—	—	—
Burgess (46)	5/10 = 50.0	44.4	42.0	24.3	36.3	35.4	45.5	78.6	70.4	—	—	211	200	32.0	28.8
Gislason (51)	21/32 = 65.6	50.5	47.9	—	—	33.6	69.6	—	—	17.0	15.7	—	—	31.6	36.7
Hudgel (53)	8/14 = 57.1	—	—	—	—	45.2	58.3	—	—	—	—	—	—	—	—
Lusk (60)	16/27 = 59.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Macaluso (61)	27/32 = 84.4	—	—	29.7	29.6	49.3	56.7	63.6	71.0	—	—	241	290	—	—
Maisel (62)	36/90 = 40.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Metes (63)	7/11 = 63.6	43.0	42.5	48.9	39.2	73.3	56.5	73.3	66.7	—	—	—	—	29.1	29.7
O'Leary (64)	8/10 = 80.0	36.6	40.0	—	—	34.6	32.0	86.6	73.0	—	—	201	186	—	—
Riley (69)	0/9 = 0	—	—	—	—	—	60.1	—	58.4	—	—	—	—	—	—
Schwartz (72)	6/13 = 46.2	38.7	38.3	—	—	72.1	67.7	81.9	90.0	—	—	—	—	34.2	32.1
Shepard (73)	8/23 = 34.8	—	—	—	—	57.0	68.0	67.0	79.0	11.0	13.0	251	246	—	—
Sher (74)	22/30 = 73.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Simmons (75)	8/18 = 44.4	—	—	—	—	40.0	49.7	60.1	53.4	—	—	—	—	—	—
Walker (76)	2/11 = 18.2	35.0	39.2	—	—	104.5	62.7	40.5	52.1	—	—	294	247	—	—
Wetmore (77)	14/27 = 51.9	—	—	39.0	35.8	66.6	61.2	57.6	73.2	—	—	—	—	—	—
Means	197/375 = 52.5	44.3	42.4	34.2	35.2	52.7	61.6	67.4	68.3	15.3	14.1	235	243	31.6	33.0
		n = 49	n = 38	n = 53	n = 27	n = 123	n = 105	n = 86	n = 78	n = 29	n = 24	n = 50	n = 36	n = 39	n = 26

Because we have excluded patients with baseline RDI < 10 where raw data made this exclusion possible, some small differences exist between our results and those in the published manuscripts.

TABLE 6. Results of analysis of Group 3 papers: baseline characteristics of responders and nonresponders

Baseline characteristic	Response defined by 50% drop in apnea index (AI)			Response defined by 50% drop in respiratory disturbance index (RDI)			Response defined by a 50% drop in either AI with final AI < 10 or RDI with final RDI < 20		
	Responders (n = 129)	Non-responders (n = 67)	p value	Responders (n = 114)	Non-responders (n = 102)	p value	Responders (n = 137)	Non-responders (n = 200)	p value
Age (years)	48.7 ± 12.5 (n = 72)	50.1 ± 11.2 (n = 47)	0.568	45.9 ± 12.1 (n = 49)	46.6 ± 11.8 (n = 49)	0.768	47.2 ± 12.8 (n = 68)	49.1 ± 11.4 (n = 129)	0.302
Apnea index	43.1 ± 27.9 (n = 129)	51.7 ± 32.5 (n = 67)	0.055	34.2 ± 24.4 (n = 53)	35.3 ± 27.8 (n = 27)	0.518	31.2 ± 23.3 (n = 92)	56.6 ± 30.5 (n = 109)	0.0001
Respiratory disturbance index	54.5 ± 28.9 (n = 59)	61.8 ± 33.4 (n = 19)	0.358	52.1 ± 30.8 (n = 114)	60.5 ± 25.0 (n = 102)	0.028	43.1 ± 26.3 (n = 100)	65.7 ± 26.7 (n = 119)	0.0001
Minimum O ₂ saturation	63.9 ± 18.0 (n = 68)	63.4 ± 9.1 (n = 21)	0.896	66.0 ± 19.1 (n = 71)	63.0 ± 18.0 (n = 56)	0.369	66.9 ± 19.0 (n = 76)	60.0 ± 18.2 (n = 66)	0.030
% REM	6.7 ± 5.3 (n = 8)	7.7 ± 5.2 (n = 4)	0.762	17.0 ± 6.7 (n = 21)	15.7 ± 7.5 (n = 9)	0.645	14.8 ± 8.0 (n = 24)	12.6 ± 7.2 (n = 18)	0.346
Weight (lb)	240 ± 69.4 (n = 78)	217 ± 53.4 (n = 31)	0.094	231 ± 52.8 (n = 46)	225 ± 55.3 (n = 39)	0.612	233.0 ± 67.0 (n = 67)	229.0 ± 60.0 (n = 88)	0.761
Body mass index (kg/m ²)	31.7 ± 6.7 (n = 39)	29.8 ± 6.2 (n = 16)	0.317	31.0 ± 4.1 (n = 33)	33.3 ± 6.9 (n = 20)	0.184	31.4 ± 5.7 (n = 48)	32.7 ± 6.9 (n = 40)	0.316

mation about the likely magnitude of the effect of UPPP on either AI or RDI. Although Table 6 suggests a trend toward AI responders having greater body weight, the Spearman correlation between weight and percentage change in AI was only 0.085 ($n = 109$, $p = 0.378$) and does not support this nonsignificant trend.

4.2.4 Location of pharyngeal narrowing or collapse

Nine Group 3 papers (22,45,53,54,61,63,65,66,69), containing raw preoperative and postoperative data on 168 patients, also presented information permitting the categorization of individual patients according to the location of narrowing or collapse. One of these papers (69) selected only patients with retrolingual narrowing or collapse, three selected only patients with retropalatal narrowing or collapse (61,65,66), and the remaining five papers included some patients with narrowing or collapse in either area. The remaining 10 Group 3 papers (30,46,48,51,56,64,71,75–77) did not provide information that permitted delineation of the location of pharyngeal narrowing or collapse in individual patients. Most of these latter papers presented data on unselected, often consecutive, patients with apnea and probably consisted of a mixed group with respect to the location of narrowing or collapse. Although we will present summary data on these papers, our analysis of the effect of the location of narrowing or collapse is restricted to the papers that provide specific patient-by-patient information. We analyzed one group of patients as though they were in the unknown-location group although CT criteria revealed

that nine of these 11 patients had pharyngeal narrowing or collapse. The authors of the report did not identify which nine patients these were (76).

The number of patients in each category based on the site of narrowing or collapse were as follows: 177 patients for whom the authors did not provide information about the location of narrowing or collapse; 111 patients, Type I only; and 57 patients, Type II or III. Table 7 contains summary information about the characteristics of these three sets of patients. However, data analyses were restricted to pairwise comparisons of the Type I versus Type II or Type III groups (the latter two groups combined for this purpose as having retrolingual narrowing or collapse).

The baseline AI in patients with Type I narrowing or collapse (38.9 ± 26) was significantly less than in patients with Type II or Type III narrowing or collapse (59.9 ± 29) ($p = 0.004$). Baseline RDI in patients with Type I narrowing or collapse (56.6 ± 29) was not quite significantly less than that in patients with Type II or Type III narrowing or collapse (64.5 ± 24) ($p = 0.096$) (Table 7).

The percentage change following UPPP in both AI ($-22.8 \pm 29\%$) and RDI ($-6.5 \pm 47\%$) in patients with Type II or Type III narrowing or collapse was significantly smaller than the decreases in AI ($-74.6 \pm 27\%$) ($p < 0.0001$) and in RDI ($-32.7 \pm 61\%$) ($p = 0.002$) in patients with Type I narrowing or collapse (Table 7). The large standard deviation indicates that some patients' RDIs increased postoperatively. The percentage increase in Min O₂ Sat was significantly greater in patients with Type I narrowing or collapse ($24.7 \pm 45\%$) than in patients with Type II or Type III narrowing or collapse ($12.7 \pm 45\%$) ($p = 0.049$). For all definitions of success, response rates

TABLE 7. Baseline and percentage-change data based on location of pharyngeal narrowing or collapse, expressed as mean \pm standard deviation

Variable	Type I (n = 111)	Type II or III (n = 57)	Unknown location (n = 177)	p value ^a
Apnea index (AI)				
Baseline	38.9 \pm 26 (n = 80)	59.9 \pm 29 (n = 21)	46.4 \pm 32 (n = 102)	0.004
Percentage change ^b	-74.6 \pm 27 (n = 77)	-22.8 \pm 29 (n = 20)	-53.6 \pm 47 (n = 94)	<0.0001
Respiratory disturbance index (RDI)				
Baseline	56.6 \pm 29 (n = 72)	64.5 \pm 24 (n = 39)	47.8 \pm 30 (n = 103)	0.096
Percentage change ^b	-32.7 \pm 61 (n = 68)	-6.5 \pm 47 (n = 37)	-32.1 \pm 58 (n = 96)	0.002
Minimum O ₂ saturation				
Baseline	63.0 \pm 15.8 (n = 55)	61.9 \pm 20 (n = 20)	66.9 \pm 20 (n = 68)	0.935
Percentage change	24.7 \pm 45 (n = 55)	12.7 \pm 45 (n = 12)	32.3 \pm 79 (n = 67)	0.049

were far higher in patients with Type I narrowing or collapse than in patients with Type II or Type III narrowing or collapse (Table 8).

The percentage of patients who attained a 50% decrease in RDI and a postoperative RDI of less than 20 (or a 50% decrease in AI and a postoperative AI of less than 10, if that index was given) was much higher for patients with Type I narrowing or collapse than for patients with Type II or Type III narrowing or collapse (52.3 vs. 5.3%) ($p < 0.0001$). The mean baseline AI for those patients with Type I narrowing or collapse who achieved this degree of improvement was significantly lower than for patients with Type I narrowing or collapse who did not respond to the procedure (30.4 ± 18.6 vs. 56.2 ± 25.9 , respectively) ($p < 0.0001$). Similarly, the mean RDI for those patients with Type I narrowing or collapse who achieved this degree of improvement was significantly lower than for patients with Type I narrowing or collapse who did not (49.8 ± 19.5 vs. 70.4 ± 27.4) ($p = 0.001$). If all patients (Types I, II, and III) are combined, 42.7% (79/185) achieved an AI of less than 10 and at least a 50% decrease in AI, and 39.2% (74/189) achieved an RDI of less than 20 and at least a 50% decrease in RDI. Using either AI or RDI as the measurement of response, response defined in this way correlated significantly only with a lower baseline AI or RDI and not with any other parameter. If response is defined as a 50% decrease in AI or RDI, with achievement of an AI of less than 10 or an RDI of less than 20, then the baseline AI and RDI are significantly higher in the nonresponder group. Using these criteria, 40.7% (137/337) of patients responded to UPPP.

4.2.5 Long-term follow-up

Our 1995 updated literature search revealed a study from 1994 in which Larsson et al. reported on long-term follow-up after UPPP (82) in a group of patients upon whom they had previously reported (59). They

followed 50 patients for a mean of 46 months (range 34 to 78 months) after UPPP. One patient died during a cardiac operation between the first and second assessments, and one patient refused long-term follow-up between the second and third assessments. At a mean of 6 months postoperatively (first assessment), 30 of the 50 patients (60%) were considered to be responders to treatment with the operation (response was defined as a postoperative RDI of less than 20 and at least a 50% postoperative reduction in RDI). At a mean of 21 months postoperatively (second assessment), 19 of the 49 patients (38.8%) were considered to be responders. Patients whose OSAS had relapsed had significant weight gains; the mean change in BMI for these patients with relapse was $+2.2 \pm 1.5$ kg/m², and for patients without relapse was $+0.5 \pm 0.7$ kg/m² ($p = 0.0135$). At a mean of 46 months postoperatively (third assessment), 24 of 48 patients (50%) were deemed responders. Weight loss, abstinence from alcohol, and positional conditioning were cited in some of those patients who sustained late improvement.

4.2.6 Complications of UPPP

Of the 37 papers addressing UPPP, 19 (44-46,49,52-54,57,58,62,63,66,68-70,72,73,77,78) made no reference to the occurrence of complications. In the 18 papers that did make reference to complications, nine (47,50,60,61,64,65,67,74,76) reported no significant or long-term complications. The remaining nine papers (43,48,51,55,56,59,71,75,78) reported the following complications: velopharyngeal insufficiency (VPI) for greater than 1 month ($n = 14$), postoperative bleeding ($n = 7$), nasopharyngeal stenosis ($n = 5$), voice change ($n = 4$), successfully managed perioperative upper-airway obstruction ($n = 2$), vague foreign-body sensation ($n = 1$) and death secondary to airway obstruction ($n = 1$). The incidence of each of these complications appears to be low. However, since over half of the papers on UPPP

TABLE 8. Response rates correlated to definition of response based on location of pharyngeal narrowing or collapse

Variable used to measure response	Response rates (%)			p value ^a
	Type I (n = 111)	Type II or III (n = 57)	Unknown location (n = 177)	
50% Decrease in AI	65/78 (83.3)	4/21 (19.0)	60/97 (61.9)	<0.0001
50% Decrease in RDI	47/70 (67.1)	9/38 (23.7)	56/97 (57.7)	<0.0001
50% Decrease in either AI or RDI	83/109 (76.1)	12/57 (21.1)	100/171 (58.5)	<0.0001
50% Decrease in RDI and a postoperative RDI < 20 or a 50% decrease in AI and a postoperative AI < 10	57/109 (52.3)	3/57 (5.3)	77/171 (45.0)	<0.0001

Some papers reported both AI and RDI as responses; consequently, the two subgroups add up to more than the sum of the two groups individually.

^a Compares patients having Type I narrowing or collapse with patients having Type II or III narrowing or collapse and does not compare unknown location. Chi-square tests are used for response-rate comparisons, Wilcoxon's two-tailed rank-sum test for percentage-change comparisons and Student's *t* tests for baseline comparisons.

^b Sample sizes for percentage changes in AI and RDI are less than sample sizes in corresponding response-rate data because of the deletion of outliers in computing means.

did not make specific comments regarding the occurrence of complications, it is impossible to determine the true incidence of complications in the population of patients under consideration. The most common complication reported is VPI greater than 1 month in duration. The difficulty of assessing the incidence of VPI is further demonstrated in the data given in the report of Zohar et al. (78). Depending on the definition used to define VPI, the incidence of VPI at 2 years after surgery was 39.4% (28/71) with mild reflux of liquids on nasal endoscopy (in most cases the patient was not aware of this subclinical VPI); 15.5% (11/71) for nasal reflux when the patient bent over a water fountain to drink water; 7% (5/71) for subclinical nasal regurgitation, i.e. patients feeling bubbles in the nose after drinking gaseous drinks; and 2.8% (2/71) for mild nasal reflux for liquids. The clinical significance of each of these definitions obviously differs. It is readily apparent, however, that the incidence of VPI is highly dependent on the rigor with which the clinician hunts it out.

Three surveys of UPPP complications that did not meet the criteria for inclusion in the analysis of UPPP results specifically addressed the rate of complications associated with the surgical treatment of OSA (83–85). Esclamado et al. (83), in a retrospective review of complications in 135 patients who underwent UPPP in conjunction with septoplasty or tracheotomy, found no significant differences between the group that had UPPP alone and those patients who had multiple procedures performed simultaneously. Ten percent of patients (14/135) had airway difficulties; seven of these were secondary to failed intubation, and the other seven occurred after extubation. Of these same 14 patients, 13 were managed successfully, but one death resulted from airway obstruction following extubation. In 2% of patients (3/135), hemorrhage occurred postoperatively and required

these patients to return to the operating room. Velopharyngeal insufficiency was not reported.

Haavisto and Suonpää (84) retrospectively reviewed the charts of 101 patients who underwent UPPP. Immediate postoperative complications were surveyed by retrospective chart review, while late complications (6 weeks, and 1 year following surgery) were surveyed by questionnaire (sent to 100 patients postoperatively and returned by 91 patients). Eleven percent of patients (11/101) had postoperative airway obstruction. Ten of these patients were managed successfully, but 1% resulted in death (1/101). Five percent (5/101) had immediate postoperative hemorrhage, which required those patients to return to the operating room. Twenty-four percent (22/91) reported persistent symptoms of VPI at 1 year, while 31% (28/91) reported dry throat, and 10% (9/91) had complaints related to swallowing. Five percent (5/91) reported breathing difficulty at 1 year postoperatively. It was not specified whether these patients referred to persistent OSAS, which would represent a nonresponse rather than a complication of UPPP.

Fairbanks (85) reported on a survey of complications solicited by mail in 1988 from all directors of residency training programs in Otolaryngology–Head and Neck Surgery in the United States. Respondents were asked to report all complications of UPPP that had come to their attention since the operation's introduction in 1979. Complications reported included both anecdotal and firsthand information, whether from the respondent's own hospital or from other hospitals in the community. Responses were returned by 72 individuals. Reported were 46 cases of nasopharyngeal stenosis; 42 cases of VPI that persisted beyond 1 month postoperatively; 16 fatalities and eight near fatalities, which most often resulted from perioperative airway obstruction; seven cases of immediate postoperative hemorrhage that required those

patients to return to the operating room; and seven cases of long-term voice change. There was no estimate of the total number of UPPP operations that had been performed in the 9-year period among the 72 locations included in the survey, and thus no estimate was made of the incidence of these complications.

4.3 Retrolingual operations

4.3.1 Tongue operations

UPPGP is a modification of UPPP performed in conjunction with a limited resection of the lateral and dorsal part of the tongue. This combined approach was developed to treat cephalometrically identified retrolingual narrowing (increased contact between the tongue and soft palate, caudally positioned hyoid, and narrow posterior-airway space). Djupesland et al. (31) studied 20 patients with a mean preoperative RDI of 54. The mean postoperative RDI of 31 at about 9 months after the operation represented a mean percentage decrease of 42.6%. Ten of the 20 patients (50%) had at least a 50% postoperative decrease in their RDIs. Another series of 19 patients treated with UPPGP had a response rate of 67% at 6 months (with response defined as a 50% reduction in AI) (32).

In two separate papers, one group of investigators evaluated the effects of tongue operations (33,34). The first paper described 12 patients who underwent an LMG procedure. All patients had significant retrolingual narrowing or collapse on physical examination and dynamic cephalometric radiographs. Fiberoptic endoscopy with Müller maneuver demonstrated a greater than 75% retrolingual narrowing or collapse. All patients had preoperative and postoperative PSG. Eleven of the patients had undergone previous UPPP, which had failed, and the 12th patient had LMG only, without previous operations, for what was felt to be primary retrolingual narrowing or collapse. With response defined as a reduction in RDI of at least 50%, the response rate was 41.7% (5/12). For the responder group, the RDI decreased from 60.6 to 14.5. Nonresponders were significantly more obese than responders ($BMI = 37.9 \pm 6.3 \text{ kg/m}^2$ vs. $30.6 \pm 4.6 \text{ kg/m}^2$, respectively) ($p < 0.05$).

The second paper (34) described patients with a modification of LMG called lingualplasty; 14 of the 22 patients had prior unsuccessful UPPP; eight of the patients had not had prior UPPP but had synchronous UPPP and lingualplasty. Lingualplasty resulted in a higher proportion of responders than did LMG. For the entire group, the mean RDI decreased from 58.6 ± 36.6 to 16.3 ± 17.2 . Response was defined as a postoperative RDI of less than 20 per hour and at least a 50% reduction from preoperative RDI. Sev-

enty-seven percent of patients (17/22) were responders; the mean RDI in the responder group decreased from 58.8 ± 39.5 to 8.8 ± 6.2 postoperatively. For the group that had previously not responded to treatment with UPPP, the response (i.e. salvage) rate was 78.6% (11/14). For this responder subgroup, the mean preoperative RDI of 50.2 ± 20.6 decreased to 8.6 ± 6.3 postoperatively. In the group that had simultaneous UPPP and lingualplasty, the response rate was 75% (6/8), and for this responder group, the mean RDI decreased from 74.7 ± 60.7 to 7.3 ± 6.4 postoperatively. Age, BMI, and cephalometric variables did not differentiate responders from nonresponders.

No permanent complications were reported for LMG. Postoperative bleeding was controlled with local cautery in 16.7% (2/12) of patients (33). Woodson and Fujita (34) studied 22 patients who had lingualplasty; three patients required general anesthesia for postoperative bleeding, and moderate odynophagia and dysphagia were common for 2 to 3 weeks postoperatively. One patient required intravenous hydration for prolonged odynophagia.

4.3.2 ISO and GAHM

Fifty-five patients had ISO [referred to as GAHM by Riley et al. (35) in their subsequent papers] for retrolingual narrowing or collapse, which was documented by fiberoptic endoscopy with Müller maneuver and cephalometry. For simplification, the term GAHM will be used in this publication. Forty-two of these patients were classified as having Type II narrowing or collapse and received both UPPP and GAHM; seven patients had previously undergone unsuccessful UPPP and, subsequently, had GAHM alone. Thus, 49 patients had UPPP and GAHM, either synchronously or at different times, and six patients, felt to have only retrolingual obstruction, underwent GAHM alone. PSG was performed at about 6 months following the operation. Definition of response was a combination of a postoperative RDI of 20 or less, at least a 50% reduction from the preoperative RDI, and minimal oxygen desaturation. Sixty-seven percent of patients (37/55) were in the responder group. These responders included 65.3% of patients (32/49) who had UPPP and GAHM (either synchronously or as separate operations) and 83.3% of patients (5/6) who had GAHM alone. The response (i.e. salvage) rate for those patients who had previously undergone failed UPPP was 85.7% (6/7). For the entire responder group, the mean preoperative RDI of 58.7 ± 23.4 decreased to 11.8 ± 6.9 postoperatively. Oxygen desaturation was largely eliminated. Weight remained unchanged. Factors that appeared to differentiate nonresponders from responders were degree of obesity

and mandibular-skeletal deficiency, with the nonresponders being more obese and more severely mandibular deficient (mean SNB = 75.5 ± 1.5 vs. 81.0 ± 2.0) than responders.

The reports of Riley et al. (86) and Johnson and Chinn (87) were discovered in our February 1995 MEDLINE update and thus were not included in the metanalysis, although they did otherwise meet the inclusion criteria. Riley et al. determined that 37.5% (9/24) of patients who underwent only inferior sagittal mandibular osteotomy and genioglossal advancement without hyoid myotomy and suspension achieved surgical response, defined as a 50% decrease from the preoperative RDI level and a postoperative RDI of less than 20. This rate compares with a response rate of 65.3% (32/49) for patients who had complete GAHM, i.e. inferior sagittal mandibular osteotomy and genioglossal advancement with hyoid myotomy and suspension. In all cases, UPPP was also performed (35,86). These findings differ from those of Johnson and Chinn (87) who reported a response rate of 77.8% (7/9) in nine patients who underwent the partial GAHM procedure (inferior sagittal mandibular osteotomy and genioglossal advancement without hyoid myotomy and suspension). They defined surgical response as a 50% decrease from the preoperative RDI level and a postoperative RDI of less than 10.

The Riley et al. data suggest that inferior sagittal mandibular osteotomy and genioglossal advancement without hyoid myotomy and suspension is a procedure of relatively low efficacy. The Johnson and Chinn data appear to contradict that conclusion. The latter authors suggest that these differences may reflect sampling error because of the small number of subjects. Although the lack of comparative cephalometric data prevents rigorous comparison between the two series, the patients in the Riley et al. series have lower mean BMI and higher mean RDI than those in the Johnson and Chinn series (mean BMI 28.6 ± 5.8 vs. 32.7 ± 1.3 and mean RDI 65.6 ± 18.3 vs. 58.0 ± 13.7). BMI was unchanged postoperatively in both groups. While not confirmed, it is possible that the patients in the Riley et al. population may have had more severe skeletal deficiency. If further analysis of the data were to support this anatomic difference, it might help to explain the difference in response rates between the two patient series (86,87).

Riley et al. applied a new, modified technique for hyoid suspension in an attempt to increase the success rate of GAHM (86). This modified procedure fixed the hyoid to the thyroid cartilage instead of to the anterior margin of the mandible. When this modified hyoid suspension was incorporated into GAHM in lieu of the original hyoid mandible suspension, the

overall response rate of GAHM (with or without UPPP depending on the presence or absence of retropalatal narrowing or collapse) was raised to 79.2% (19/24). Of the five nonresponders, three achieved RDIs close to levels at which they would have been considered responders, i.e. an RDI of 21 from 102, 25 from 62, and 26 from 40. The mean BMI remained unchanged.

Of 55 patients treated with GAHM (prior to modification of the hyoid suspension technique), one had a wound infection resulting in a mandibular fracture that responded to antibiotics and closed reduction. All patients developed transient anesthesia of the lower anterior teeth, and two patients (3.6%) sustained injury to an incisor as a result of the osteotomy (35).

4.3.3 MMO

To treat OSAS, Riley et al. adopted MMO, a technique that modifies the airway space by advancing the maxilla, the mandible, and, thus, the tongue (36). They studied 30 patients and determined the site(s) of obstruction by fiberoptic endoscopy with Müller maneuver and cephalometric analysis. Patients with Type II narrowing or collapse ($n = 25$) were treated in two stages. They underwent a UPPP procedure for retropalatal obstruction and, if this first stage of the operation was documented to have failed, a maxillo-mandibular and hyoid advancement were performed for treatment of the retrolingual obstruction. Patients with Type III narrowing or collapse ($n = 5$) were treated with maxillomandibular and hyoid advancement as the first stage. Patients from both groups were, as a whole, morbidly obese, with a mean BMI of 32.6 ± 6.0 kg/m². The mean BMI was unchanged postoperatively. The mean preoperative and postoperative RDIs were 72.0 ± 25.8 and 8.8 ± 6.1 , respectively. Oxygen desaturation was nearly eliminated. The percentage of REM sleep increased from $8.7 \pm 5.0\%$ to $21.1 \pm 5.2\%$; stage 3 and stage 4 sleep increased from $2.3 \pm 4.2\%$ to $8.4 \pm 3.2\%$.

The same group of investigators established a protocol of two-stage treatment and surgically treated 415 patients with OSAS. Their report included data on only 306 of the patients because 109 either did not receive postoperative PSG or were lost to follow-up (37). Fiberoptic endoscopy with Müller maneuver and lateral cephalometric roentgenography were used to classify the obstructive pattern as Type I, II, or III. A two-stage treatment protocol incorporated different approaches for patients documented to have a different site or different sites of pharyngeal obstruction. Stage 1 operations consisted of UPPP for patients with Type I narrowing or collapse, UPPP and GAHM synchronously for patients with Type II narrowing or

collapse, and GAHM for patients with Type III narrowing or collapse. A Stage 2 operation (MMO) was performed only after it had been demonstrated by PSG at least 6 months postoperatively that Stage 1 operations had failed. Response was defined by a postoperative (at 6 months) RDI of less than 20, representing at least a 50% reduction from preoperative RDI, and the lowest oxygen saturation equivalent to that of a second night of CPAP titration.

For the 306 patients, the mean preoperative demographic data were: age, 47.2 ± 11.2 years; gender, 35 females and 271 males; BMI, 30.5 ± 5.8 kg/m²; RDI, 55.8 ± 26.7 ; and Min O₂ Sat, $70.5 \pm 15.8\%$. The overall degree of response in Stage 1 operations was 61.1% (146/239). After UPPP, patients with Type I narrowing or collapse had a response rate of 80% (8/10). After GAHM and UPPP, patients with Type II narrowing or collapse had a response rate of 57.1% (133/233). After GAHM, patients with Type III narrowing or collapse had a response rate of 66.7% (4/6). The likelihood of response tended to diminish with increasing preoperative apnea severity as follows: i) for patients with a preoperative RDI of less than 20, the response rate was 76.9% (20/26); ii) for patients with a preoperative RDI of 20 to 40, the response rate was 77.6% (45/58); iii) for patients with a preoperative RDI of 40 to 60, the response rate was 70.6% (36/51); iv) for patients with a preoperative RDI of greater than 60, the response rate was 42.3% (44/104). Most patients with unsuccessful Stage 1 operations had severe apnea (mean RDI, 61.9) and morbid obesity (mean BMI, 32.3 kg/m²).

Of the 91 patients who had Stage 2 operations (MMO), 24 had undergone unsuccessful Stage 1 operations performed by the investigators, 60 had undergone unsuccessful UPPP elsewhere, and seven had primary facial skeletal deformities, some with dental malocclusion. The overall response rate for Stage 2 operations was 97.8% (89/91) at a mean follow-up time of 9 months. The mean preoperative RDI decreased from 68.3 ± 23 to 8.4 ± 5.9 . The mean Min O₂ Sat increased from 63.2 ± 17.5 to 86.6 ± 3.4 . The mean percentage of stage 3 and stage 4 sleep increased from $2.9 \pm 4.4\%$ to $8.2 \pm 7.7\%$, and the mean percentage of REM sleep increased from $8.9 \pm 4.0\%$ to $19.1 \pm 6.0\%$.

Another group of authors (42) reported their treatment of 23 patients. They devised a protocol in which MMO was the primary surgical approach for those patients with abnormal anatomy (as determined by cephalometric measurements) and performed other adjunctive procedures only if they felt further treatment was indicated (based on observed pharyngeal abnormalities). Adjunctive procedures included sliding horizontal genioplasty ($n = 15$), partial glossec-

tomy ($n = 8$), and UPPP ($n = 7$). Five patients in the UPPP group had previously undergone unsuccessful UPPP. Seventy-eight percent of patients (18/23) had adjunctive procedures and 52.2% (12/23) had two adjunctive procedures.

Response was defined as a postoperative (at 6 weeks) RDI of less than 10. The response rate for the group that had MMO with no adjunctive procedure was 20% (1/5). The response rate for the group having MMO and at least one adjunctive procedure was 77.8% (14/18). The response rate for the patients who had MMO and UPPP as their only adjunctive procedure, or as one of at least two adjunctive procedures, was 100% (7/7). There was no statistical difference between the responders and nonresponders in terms of cephalometric measures, weight loss, apnea severity, or degree of maxillomandibular osteotomy and advancement.

In a report discovered in our February 1995 MEDLINE update, Hochban et al. (88), reported on a series of 21 consecutive patients treated for OSA with MMO as the sole treatment in 20 of 21 cases. All 20 patients achieved a postoperative RDI of less than 10 (mean preoperative RDI, 44.9 ± 17.5 ; mean postoperative RDI, 3.5 ± 4.7). The one patient in whom the procedure failed required UPPP and palatal advancement as adjunctive procedures. The group was skeletally deficient (mean preoperative SNA, 79.6 ± 3.4 ; mean preoperative SNB, 75.2 ± 4.0) and nonobese (mean preoperative BMI, 27.0 ± 3.2 kg/m²). The mean apnea severity was moderate (mean preoperative RDI, 44.9 ± 17.5).

Riley et al. (37), reported that all of the 306 patients who underwent maxillomandibular operations (GAHM or MMO) developed transient anesthesia of the cheek and chin area, which resolved in 87% of patients in 6 to 12 months. No patients in this group experienced motor nerve deficits, postoperative bleeding, or major skeletal relapse. Waite et al. (42) reported that of their 23 patients who underwent MMO, 12% developed cardiac arrhythmias, including cardiac arrest.

4.4 Tracheotomy

This review included three series of patients who underwent tracheotomy (39–41). In one series of 11 patients (39), the indications for treatment were cor pulmonale (4/11), chronic alveolar hypoventilation (5/11), nocturnal arrhythmia (4/11), and disabling somnolence (9/11). During the follow-up period (up to 3 years; mean, 17 months), EDS and sleep disruption resolved in nine of the 11 patients. Central apnea and alcohol or drug abuse accounted for the persistence of these symptoms in the remaining two pa-

tients. Chronic hypercapnia resolved in six of six patients. Cor pulmonale resolved in all patients so affected but recurred in one. Cardiac arrhythmias resolved or improved in all affected patients. Hypertension resolved in two of the five patients with high blood pressure. Patients who lost weight initially after tracheotomy gained it back within 6 months. Local complications included psychosocial problems resulting from having a tracheostomy in 10 patients, granulation-tissue formation resulting in hemoptysis or obstruction in nine patients, and recurrent bronchitis in six patients. The number of patients who were unable to work increased from two to seven after tracheotomy, generally as the result of employer concerns regarding liability.

In a series of 50 patients who were followed for up to 6 years (mean, 32 months), indications for tracheotomy were disabling EDS, severe cardiac arrhythmias, an AI of greater than 60, and a Min O₂ Sat of less than 40% (40). Thirty patients were hypertensive and 25 were taking antihypertensive medications. PSG was conducted within 6 days postoperatively in 30 patients. Results of 83.3% of these tests (25/30) demonstrated a resolution of OSA, and the patients were free of EDS. Ultimately, 100% of patients had a resolution of their EDS. Only 6.7% (2/30) of hypertensive patients became normotensive postoperatively; however, of the 25 patients previously taking antihypertensive medication, 40% (10/25) required less vigorous medical therapy for their hypertension. Ninety-four percent of patients (47/50) returned to work or school. All patients achieved an AI of less than 5; an increased central apnea that appeared shortly after the tracheotomy was performed resolved over time. Sleep architecture became normal. All attempts at closure of the tracheostomies resulted in reappearance of the OSA. Forty-two percent of patients (21/50) developed granulation tissue at the tracheostomy site (40).

In a third series of 38 patients, 10 had preoperative and postoperative PSG (41). All 38 patients were overweight and hypertensive. Indications for tracheotomy included severe EDS, serious cardiac arrhythmias, past history of cardiac or cerebrovascular disease, and systemic hypertension. The EDS resolved in all patients within 48 hours postoperatively. PSG performed postoperatively (within 9 days in nine patients and on day 41 in the 10th) showed that the number of mixed and obstructive apneas became normal and the number of central events and hypopneas increased. Tracheostomy could be closed in only one patient who lost a considerable amount of weight (41).

5.0 DISCUSSION

5.1 Discussion of results

In 1981, Fujita (30) introduced UPPP as the first specialized surgical procedure to treat OSAS and arbitrarily selected a postoperative decrease in AI of at least 50% from its preoperative value as the criterion for surgical response. The current understanding of OSAS mandates a more restrictive criterion, one that takes into account not only apneas but also hypopneas and, possibly, even subobstructive events that result in arousal (89–91). A more meaningful definition of response must also include parameters relating to improvement in oxygenation, sleep architecture, EDS, or a combination of these measures. While fractional improvement may be of significant benefit, achievement of the threshold level of apnea severity at which there is no significant morbidity or mortality would appear to be the desired goal. While many authors currently use an RDI of 20 as such a level, this number is based on limited mortality data reported by He et al. (18), which indeed looked at AI and not RDI. The real threshold below which apnea severity becomes inconsequential will be determined only through future investigation.

The paradigm that classifies pharyngeal functional anatomy into Types I, II, and III is likely an oversimplification. This classification system has, however, led to a greater understanding of the limitations inherent in UPPP and has resulted in the development of new and promising surgical procedures for the treatment of OSAS. The common goal of UPPP and these newer procedures is to augment the upper airway, and each procedure is designed to alter specific portions of that compromised region. While a number of investigators have attempted, using differing techniques, to better define the localized variations in pharyngeal narrowing, there is no universally accepted and validated clinical method for doing so. The methods that appear to be most clinically useful at this time are fiberoptic endoscopy (with or without Müller maneuver) and lateral cephalometry.

The site of pharyngeal narrowing or collapse, though identified by different methods (none of which is validated or universally accepted for this clinical purpose) has a marked effect on the probability of the success of UPPP. While not clearly demonstrated by most of the individual papers, possibly because of small sample sizes, the impact of site of narrowing or collapse is demonstrated by analysis of the pooled data. Following UPPP, the percentage change in both AI and RDI differs greatly depending on the location of narrowing or collapse. The percentage change in AI is $-74.6 \pm 27\%$ for patients with Type I narrow-

ing or collapse and $-22.8 \pm 27\%$ for patients with Type II and Type III narrowing or collapse ($p < 0.0001$). The percentage change in RDI is $-32.7 \pm 61\%$ for patients with Type I narrowing or collapse and $-6.5 \pm 47\%$ for patients with Type II and Type III narrowing or collapse ($p = 0.002$). Similarly, the response rates differ greatly, depending on the location of narrowing or collapse. When defined as a 50% decrease in AI, the response rate is 83.3% for patients with Type I narrowing or collapse versus 19.0% for patients with Type II and Type III narrowing or collapse ($p < 0.0001$). When defined as a 50% decrease in RDI, the response rate is 67.1% for patients with Type I narrowing or collapse versus 23.7% for patients with Type II and Type III narrowing or collapse ($p < 0.0001$). However, even for patients with Type I narrowing or collapse, the rate of response for UPPP is only 52.3% if response is defined by both a 50% decrease in RDI or AI and a postoperative RDI of less than 20 or AI of less than 10. The patients with Type I narrowing or collapse who achieved this high level of response had a lower baseline AI than did those patients who did not achieve such levels (30.4 vs. 56.2, respectively). Response, defined by this strict criterion, occurred in only 5.3% of patients with Type II and Type III narrowing or collapse. For the entire population, combining patients with Types I, II, and III narrowing or collapse, 40.7% (137/337) achieved response defined by an AI of less than 10 or an RDI of less than 20 and at least a 50% decrease from the baseline index. Response by these definitions was significantly correlated with only lower baseline AI and RDI. The ideal patient for treatment with UPPP appears to be one who has a locus of pharyngeal-airway narrowing or collapse limited to the retropalatal region.

It would appear from the data reviewed that successful surgical treatment of OSAS requires judicious selection from among currently available surgical techniques. Region-by-region analysis of the individual patient's pattern of airway compromise should guide the selection process. Procedures deemed appropriate after such analysis should be applied. For effective treatment of patients with significant retrolingual narrowing or collapse, procedures that enlarge that portion of the airway must be applied. More than one procedure may be necessary, depending on the complexity of the anatomic compromise and the severity of the OSAS. In such cases, multiple procedures can be performed synchronously or in a staged fashion. Staged procedures, with documentation of persistent postoperative apnea serving as the justification for further operations, may maximize improvement while minimizing the total number of different surgical procedures ultimately performed. While

these goals are desirable, the price paid is the necessity for multiple hospitalizations, anesthetic procedures, and periods of convalescence. The armamentarium of available surgical procedures, if applied in a logical fashion under a comprehensive protocol, may effectively treat the vast majority of patients with OSAS, regardless of the nature of their deviant anatomy or the severity of their apnea. Ninety-eight percent of patients (89/91) who completed the treatment or sequence of treatments mandated by this type of protocol had successful treatment of their OSAS according to stringent criteria of response (37).

However, the technique or techniques that most effectively identify the pattern of airway compromise and narrowing or collapse have not been determined. Furthermore, the degree to which this classification is an oversimplification is uncertain. Research in both of these areas is ongoing. Since our 1993 literature search and subsequent metanalysis, several more reports have been published that illustrate some of the questions and uncertainties relating to the selection process.

Skatvedt (92) subjected 10 patients treated with UPPGP to preoperative and postoperative PSG and pharyngeal manometry. The mean preoperative and postoperative RDIs of these patients were 56.2 and 14.0, respectively. Seven patients continued to demonstrate postoperative pharyngeal obstruction in the caudal nasopharynx and rostral pharynx during sleep. Most patients had obstruction in more than one anatomic region, and the number of obstructed regions was greatest in those patients with the highest RDIs and BMIs. Persistent obstruction in patients after UPPGP was always localized to the nasopharynx and the junction of the nasopharynx with the pharynx.

Using preoperative and postoperative (asleep) endoscopy in conjunction with manometry, Woodson and Wooten (93) studied 11 patients whose OSAS did not respond to UPPP (six patients had UPPP as the sole procedure, two had UPPP with palatal advancement, and three had UPPP with operations of the tongue base). The preoperative RDI was greater than 50 in all patients; the mean RDI was 82.4 ± 20.6 , and the mean BMI was $38.1 \pm 11.3 \text{ kg/m}^2$. The authors defined response as at least a 50% decrease in postoperative RDI. The results of manometry documented that most UPPP failures occurred in patients whose initial postoperative level of obstruction was at the palate. Secondary tongue-base collapse was frequently documented by endoscopy and missed by manometry.

Petri et al. (94) subjected 30 patients (median preoperative AI = 26) to UPPP with and without tonsillectomy, depending on assessed tonsillar size. Response (defined as a greater than 50% reduction in

postoperative AI from preoperative levels and a postoperative AI of less than 20) was achieved in 63% of patients. Endoscopy with Müller maneuver did not predict outcome, whereas cephalometry proved to be of predictive value.

Schäfer (95) used acoustic spectral analysis of snoring sounds to predict the success or failure of UPPP in 64 patients whose preoperative RDIs were greater than 10. The mean postoperative RDI was 32.2 ± 18.6 and the mean BMI was 28.6 ± 3.4 kg/m². The response rate, defined as a postoperative RDI of less than 10, was 51.6% (33/64). The positive predictive value of frequency spectral analysis was 76%, and the negative predictive value was 78%.

In addition to the ongoing research into the identification of the site of pharyngeal narrowing or collapse and the subsequent utility of that information, studies addressing the staging of surgical procedures also raise interesting questions. The work of Riley et al. (37) and that of Waite et al. (42) suggest that correction of anatomically complex deficiencies in patients with OSA should initially be attempted by application of limited surgical procedures such as UPPP and/or GAHM (singly or together depending on the patient's pattern of pharyngeal compromise). MMO is then reserved for nonresponders. On the other hand, Hochban et al. (88) indicates that primary MMO may be appropriate in some patients. The approach described by Hochban et al. differs from that reported by Riley et al. (37) in that Hochban et al. did not perform Stage 1 procedures before MMO and instead used MMO as the primary method of treatment. The achievement of response in 20 of 21 cases would suggest that Stage 1 operations might be unnecessary to achieve a high rate of cure (assuming one were willing to accept MMO as the primary modality). The surgical results reported by Hochban et al. also contrast with those of Waite et al. (42). In the latter study, MMO was applied as a sole or primary therapy and resulted in a low rate of cure. Only one of five patients having MMO alone responded to the operation (response defined as postoperative RDI of less than 10). If, however, at least one adjunctive procedure (Stage 1 type) was done in addition to MMO, the rate of success increased to 77.8% (14/18) (42). Lack of comparable preoperative patient-descriptive data prevents adequate analysis of the three patient populations in relation to one another (37,42,88). It is noted, however, that the population treated with staged procedures by Riley et al. (37) had more severe OSA and were obese, whereas the group treated by Hochban et al. had less severe OSA and were non-obese. Patients in the reports of Riley et al. and Hochban et al. had skeletal deficiencies of approximately equal degree. Therefore, the group reported on by

Hochban et al. may represent a subclass of the Stage 2 population in the series of Riley et al., i.e. nonobese, severely skeletally deficient, and with moderately severe OSA. Within the group of 91 patients undergoing MMO in the series of Riley et al., seven patients started therapy with Stage 2 (MMO) without undergoing Stage 1 operations. These seven patients had severe skeletal deficiency warranting primary MMO. Thus, some nonobese but skeletally deficient patients may be appropriately treated with Stage 2 procedures (MMO) alone.

5.2 Weaknesses and limitations of data

The authors of this report discuss (in a separate publication) methodologic and statistical problems that are associated with many of the UPPP papers in further detail (96). The following are among the more important limitations.

5.2.1 Study design

All of the reviewed studies present Sackett's Level III or Level V evidence (97), i.e. either nonrandomized concurrent cohort comparisons between contemporaneous patients who did and did not have therapy, or case series without controls. To our knowledge, no randomized, controlled studies regarding the surgical treatment of OSAS have been published in peer-reviewed journals. However, the nature of the treatments under consideration does not readily lend itself to randomized double-blind studies.

5.2.2 Thoroughness and duration of follow-up

In most reports, follow-up data are available for only a subgroup of patients who underwent therapy, and this subgroup does not represent universal follow-up. Bias introduced by this deficiency is potentially significant, and the direction and degree of bias is difficult to estimate. The great majority of data represent short-term reporting; only a fraction of patients had long-term follow-up. While it appears that some of the immediate postoperative gains may not be uniformly maintained, particularly after UPPP, the extent to which this is the case is not adequately delineated.

5.2.3 Uniformity in reporting results of PSG

A lack of uniformity exists in reporting the results of PSG. For instance, data on AI are given in 60% of the UPPP papers, while data on RDI are given in 47%. The impact of therapy on percentage of REM sleep is covered in only 20% of papers, while similar

data for stages 3 and 4 sleep are available in 16%. Oxygen desaturation associated with OSAS is measured in terms of Min O₂ Sat in 53% of papers and by five other descriptive measures in those remaining papers in which some measure of oxygenation is described. The lack of uniformity in reporting may reflect uncertainty about what measures are most clinically significant but creates further uncertainty in the interpretation of clinical outcomes. Different clinical series, in which preoperative and postoperative status are reported in terms of differing parameters, cannot be readily compared. The lack of data in many reports makes it impossible to ascertain the impact of therapy on significant aspects of OSAS. For example, despite the relatively large combined patient population represented in the series of papers on UPPP, data on sleep architecture are extremely sparse and do not permit an adequate assessment of the effect of UPPP on sleep architecture.

5.2.4 Lack of valid measures of sleep-related health status and quality of life

This report has emphasized improvement based on the assumption that objective PSG data are the appropriate measure of clinical response. Little weight was given to subjective patient-based reports about quality of life. Thus, aside from general comments about patients being less tired and about their snoring less frequently or less loudly, no information precisely quantifies the relationship between operations for the treatment of OSAS and quality of life. Further research is needed to establish which parameters of severity, subjective and objective, have the greatest relevance to short-term and long-term morbidity and mortality from OSAS. The level of severity below which persistent apnea ceases to have an association with increased long-term morbidity and mortality must be established. These advances would facilitate a more clinically relevant assessment of surgical outcomes for OSAS.

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APPENDIX A: DEFINITION OF TERMS

Apnea: a cessation in breathing at least 10 seconds in duration.

Apnea index (AI): number of apneas per hour of sleep.

Body mass index (BMI): ratio of weight (kg) to height (m) squared, i.e. kg/m².

Excess body weight: actual weight minus ideal body weight.

Hypopnea: a reduction without complete cessation of breathing of at least 10 seconds duration, reflecting a partial obstruction of the airway (if obstructive), and frequently characterized by oxygen desaturation, arousal, or both.

Mandibular plane-hyoid distance (MPH): a cephalometric measure that reflects the vertical distance between the most anterior or superior point on the body of the hyoid and the mandibular plane, a plane constructed through gonion and gnathion. (Gonion is the most posterior or inferior point on the convexity of the angle of the mandible. Gnathion is the most inferior point in the contour of the chin.)

Minimum oxygen saturation (Min O₂ Sat): minimum oxygen saturation associated with an apnea.

Obstructive sleep apnea syndrome (OSAS): a clinical syndrome related to an increased frequency of respiratory disturbance due to upper-airway obstruction.

Posterior airway space: a cephalometric measurement, representing the narrowest dimension between the base of the tongue and the posterior pharyngeal wall, in mm.

Respiratory disturbance index (RDI): the number of apneas plus hypopneas per hour of sleep (sometimes referred to as apnea-hypopnea index).

SNA: cephalometric angle, measured in degrees, formed by lines joining S (sella, midpoint of sella turcica), N (nasion, the most anterior point of the nasofrontal suture) and A (the deepest point of contour of the premaxilla between anterior nasal spine and central incisors).

SNB: cephalometric angle, measured in degrees,

formed by lines joining S (sella, midpoint of sella turcica), N (nasion, the most anterior point of the nasofrontal suture), and B supramentale (the deepest point of contour of the mandibular alveolus between pogonion and central incisor, with pogonion being the most anterior point of the contour of the chin).