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What is “Success” Following Surgery for Obstructive Sleep Apnea?: The Effect of Different Polysomnographic Scoring Systems

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Objectives/Hypothesis: To illustrate that the diagnosis of obstructive sleep apnea (OSA) is dependent on the polysomnographic scoring criteria used, and the success rates of treatments for OSA are dependent on the defined outcome measures.

Study Design: Retrospective case series with prospective reanalysis of polysomnographic data.

Methods: Consecutively treated adult patients ($N = 40$) with moderate to severe OSA having multilevel pharyngeal surgery in 2007 were studied. All patients underwent submucosal lingualplasty and concurrent or previous uvulopalatopharyngoplasty ± palatal advancement. Full polysomnography (PSG) was performed preoperatively and at a mean of 145 days postoperatively. Pre- and postoperative PSG data were analyzed by two different but widely used scoring systems for the apnea-hypopnea index (AHI): The American Academy of Sleep Medicine (AASM) 1999 Chicago criteria and the AASM 2007 recommended criteria.

Results: Follow-up PSG data were available in 31 of 40 patients. Successful surgery was defined as a reduction in AHI_{Rec} <20 with a 50% reduction from the patient's baseline, and in this group the surgical intervention was associated with a 72.2% success rate. If, however, differing AHI metrics are used or the absolute or percent reduction used to define a successful outcome is changed, then the rate of surgical success is shown to range from 39% to 92%.

Conclusions: Different criteria for measuring AHI and defining success following OSA surgery can produce widely conflicting outcome data. Reported results following OSA surgery should be interpreted with this in mind. Using acceptable criteria, multilevel sleep surgery can be demonstrated to be of benefit to the majority of carefully selected patients.

Key Words: Surgery, sleep apnea, evidence, treatment effectiveness, health outcomes.
Level of Evidence: 2b

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INTRODUCTION

Obstructive sleep apnea (OSA) is a common disorder seen by general practitioners, sleep physicians, and otolaryngologists. It affects 2% to 4% of the adult population.[1] To diagnose OSA, objective testing by means of polysomnography (PSG) is performed. OSA is caused by repeated episodes of upper airway obstruction resulting in cessation (apnea) or reduction (hypopnea) in airflow during sleep. The apnea-hypopnea index (AHI) reflects the number of apneas and hypopneas per hour of sleep. OSA syndrome is confirmed by an elevated AHI in a patient who is symptomatic.[1] The scoring methods used to calculate the AHI have varied over time. The American Academy of Sleep Medicine (AASM) produced a consensus report recommending the standardization of scoring for respiratory events in clinical research in 1999. These guidelines have subsequently been revised and re-revised in 2001 and 2005, respectively; a summary of these guidelines is shown in Table I.

Surgery can be considered as a second-line treatment for OSA when the outcome of continuous positive airway pressure (CPAP) is inadequate or CPAP is not tolerated by the patient.[2] Surgery can also be of benefit as an adjunct when obstructive anatomy or functional deficiencies compromise other therapies.[1] Although good surgical results have been reported from several centers,[3,4] others claim that results are so poor that investment in this type of surgery should be discontinued.[5] Interpretation of the literature remains problematical as authors continue to use different AHI criteria for investigation and different AHI thresholds for defining surgical success. Elshaug et al. proposes that *cure* be defined as an $AHI_{(unspecified)}$ of

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TABLE I.
The Three Different Definitions of Apnea-Hypopnea Index.

$AHI_{Chicago}$	>50% decrease in a valid measure of air flow, or a lesser airflow reduction in association with an oxygen desaturation of >3%, or an arousal
AHI_{Rec}	Abnormal respiratory event lasting ≥10 seconds, with ≥30% reduction in thoracoabdominal movement or airflow, and with ≥4% oxygen desaturation
AHI_{Alt}	≥50% reduction in nasal pressure signal excursions and ≥3% desaturation or arousal

AHI = apnea-hypopnea index.

<5,[6] but there is poor correlation of the AHI with patient-oriented outcomes,[7] and using this metric alone as a definition of success risks emphasizing statistically significant outcomes over clinical outcomes.

The aim of this study was to assess a consecutive group of patients undergoing multilevel pharyngeal surgery as a second-line treatment for OSA, and in particular to reanalyze their PSG data according to $AHI_{Chicago}$ and AHI_{Rec} and ascertain the impacts of these different scoring techniques on what might be regarded as a surgical success. Although to some, cure defines success and lack of cure defines failure,[5,6] but this is a potentially unhelpful paradigm in the OSA patient where the main therapy (CPAP) offers no benefit due to lack of compliance or patient rejection. To these ends, the physiological, symptomatic, and clinical improvement offered by surgical intervention make it compelling to consider even in the absence of total normalization of the polysomnographic outcome.[8]

MATERIALS AND METHODS

A total of 40 patients with moderate to severe OSA undergoing multilevel pharyngeal surgery were studied. The patients all had a patent nasal airway documented preoperatively. Patients with morbid obesity (body mass index [BMI] >40) were excluded and referred for weight loss or bariatric surgery. Patients with severe skeletal deficiency (cephalometric evidence of sella-nasion-B angle <72°) were advised to continue their CPAP and referred to maxillofacial surgeons for consideration of maxillomandibular advancement.[9] All of the patients had undergone previous uvulopalatoplasty and/or palatal advancement as part of the stepwise pharyngeal surgical protocol performed at this institution and previously described.[3] Lingual reduction was undertaken due to persistent macroglossia defined as clinical findings of a Friedman oral tongue size 3 or 4, moderate or severe endoscopic macroglossia (obscuring at least part of the view of the vocal cords in supine midrespiration awake nasoendoscopic examination), or a genioglossus midsaggital area of $>26cm^2$ on spiral computed tomography scan, defining a greater than average adult tongue size.[10] The submucosal lingualplasty technique has been described previously.[9]

Approval for this study was granted by the Flinders Clinical Research Ethics Committee. The patients studied were sent a preoperative questionnaire consisting of the Snoring Severity Scale (SSS) and Epworth Sleepiness Scale (ESS). A preoperative PSG was performed in a sleep laboratory attended by overnight sleep technicians. The recording was conducted and analyzed using computerized equipment (E-series) and software (Profusion PSG) from Compumedics Diagnostics Ltd. (Abbotsford, Victoria, Australia), with manual scoring done by a single sleep technician accredited by the Board of Registered Polysomnographic Technologists and regular participant in an external proficiency testing program. The PSG was scored for both $AHI_{Chicago}$ and AHI_{Rec}. The repeat assessment, including polysomnography, was undertaken 3.74 ± 0.38 months (mean ± standard deviation) postoperatively. Patients were classified as having a successful response to surgery if they had a postoperative AHI_{Rec} ≤20 with a 50% reduction in AHI from baseline. This criterion has previously been defined as the traditional marker of surgical success in surgery for OSA.[6]

RESULTS

A total of 32 males and eight females were studied. The mean age was 52.5 years. Only 27 patients completed both pre- and postoperative questionnaires. Thirty-one patients had a complete polysomnographic data set pre- and postoperatively as recommended by the AASM.[11] Subsequent data are reported as median (± standard error median).

Symptomatic snoring remained well controlled after surgery with the SSS falling from 8.00 (± 0.64) to 0.00 (± 0.79) ($P < .001$). The ESS fell from 7.00 (± 1.77) to 4.0 (±1.22) ($P = .004$) (Table II).

The overall cohort AHI_{Rec} fell from 31.80 (± 4.90) to 7.50 (± 1.51) ($P < .001$). There are various criteria of success (see below), but using a definition of a postoperative AHI <20, 83.3% of the cohort had a successful outcome. The rate of success ranged from 38.9% to 91.7% depending on the criteria and metric used to define a successful outcome and is tabulated in Table III; an infographic showing the numbers of successful outcomes is shown in Figure 1. The lowest oxygen saturation improved from 84.35% (± 1.07) to 87.96% (± 1.26), and the BMI remained essentially stable, changing from 30.73 (± 1.02) to 29.82 (± 0.91) (not significant) postoperatively.

The most serious complication was seen in 2/40 (5%) of patients who suffered delayed bleeding and

TABLE II.
Preoperative and Postoperative Patient Outcomes.

Outcome Measure/Variable	Preoperative	Postoperative
Epworth Sleepiness Scale	7.00 (±1.77)	4.00 (±1.22)
Snoring Severity Scale	8.00 ±0.64)	0.00 (±0.79)
AHI_{Rec}	31.80 (±4.90)	7.50 (±1.51)
Lowest O_2 saturation	84.35% (±1.07)	87.96% (±1.26)
Body mass index	30.73 (±1.02)	29.82 (±0.91)

AHI = apnea-hypopnea index.

TABLE III.
Percentages of Patients Reported as Having a Successful Outcome Where Success Is Defined According to the Tabulated Criteria Using the Two Metrics $AHI_{Chicago}$ and AHI_{Rec}.

Criteria of Success	AHI_{Rec}, %	$AHI_{Chicago}$, %
AHI <30	91.7	75
AHI <20	83.3	52.8
AHI reduced by 50%	77.8	55.6
AHI <20 and reduced by 50%	72.2	38.9

AHI = apnea-hypopnea index.

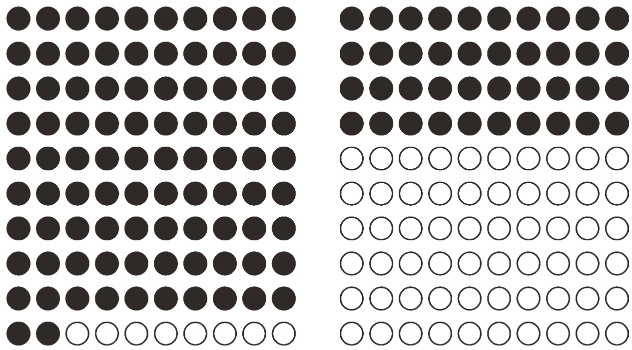

Fig. 1. Infographic showing proportion of successfully treated patients using a best case scenario (apnea-hypopnea index [AHI] <30 defined by AHI_{Rec}) on the left and a worse case scenario (AHI <20 and reduced by 50% defined by $AHI_{Chicago}$) on the right. Filled circles indicate percentage of successfully treated patients; open circles show treatment failures.

tongue hematoma. Tongue wound dehiscence paralleled wound infection. Overall, this was seen in 35.1%, with a marked reduction in rate seen on changing the closure suture material from braided (50%, n = 12/24) to monofilament (7.7%, n = 1/13) (P = .013). Short-term alteration in tongue function was frequently seen initially, with the proportion of patients reporting some change in speech, swallowing, and taste being 96%, 85%, and 48%, respectively. No hypoglossal nerve weakness was noted in any cases. Long-term globus pharyngeus symptoms were described in 4% (n = 1/27).

DISCUSSION

Patients often seek treatment of OSA because of their symptoms; however, the consequences of OSA may go unrecognized by the patient and include increased risk of: hypertension,[12] congestive heart failure,[13] atrial fibrillation,[14] myocardial infarction,[15] diabetes mellitus,[16] cerebrovascular accident,[17] neurocognitive impairment,[18] and increased risk of motor vehicular accidents.[19] Treatment aims of any OSA therapy are to control symptoms and minimize long-term morbidity by reducing the frequency of apnea and hypopneas. These aims appear straightforward, and for an intervention to be successful it should achieve this. The difficulty arises in quantifying and determining whether an intervention has fulfilled these aims. The practice parameters of the AASM state that the desired outcome of treatment includes resolution of the clinical signs and symptoms of OSA and normalization of sleep quality, AHI, and oxyhemoglobin saturation.[20] They state that the AHI does not encompass all dimensions of OSA but stipulate that because an abnormal AHI is necessary for disease classification, its normalization is an important treatment objective. Elshaug et al. also proposes that surgical audits and outcome studies should report objective cure rates with success based on AHI outcomes of ≤ 5 and/or ≤ 10.[6] The rationale behind this are studies investigating CPAP treatment for OSA that have shown minimal reduction in arterial blood pressure with a 50% reduction in AHI, compared to a significant drop in arterial blood pressure following a 95% reduction in AHI.[21] The problem with this approach is that polysomnographic parameters as outcome measures are important surrogates of some clinical outcomes, such as cardiovascular risk, but they should not be mistaken for clinical outcomes themselves.[8]

Whereas an apnea has consistently been defined as the cessation of airflow for >10 seconds, hypopneas have been a floating metric.[22] Ruehland et al. has shown in an elegant study of 328 PSGs of patients being investigated for OSA that using the different published standard AHI definitions leads to marked differences in AHI.[23] The median AHI_{Rec} was approximately 30% of the median $AHI_{Chicago}$, whereas the median AHI_{Alt} was approximately 60% of the $AHI_{Chicago}$. The implication of this is that approximately 40% of patients classified as positive for OSA using $AHI_{Chicago}$ would be negative using AHI_{Rec}, and 25% would be negative using AHI_{Alt}. To further compound matters, the detection of nasal airflow is said to be more sensitive with more events detected when using a pressure transducer rather than a thermistor.[24] Punjabi et al.'s work[25] shows that the apnea index and hypopnea index at varying oxyhemoglobin desaturation thresholds are only modestly correlated (r = 0.15-0.40), indicating that although apneas and hypopneas co-occur, there is moderate heterogeneity. Further analysis of a cohort of over 6,000 patients reveals that only hypopneas defined by a definition of oxyhemoglobin desaturation >4% were associated with cardiovascular disease. This definition corresponds to AHI_{Rec}. The corollary of this is that aiming to normalize the AHI depends on the metrics used to define the AHI. Obtaining an $AHI_{Rec} \leq 10$ may be sufficient and require a lesser intervention (albeit less extensive surgery or lower CPAP pressure) than obtaining an $AHI_{Chicago} < 10$. The three different definitions are tabulated in Table I.

CPAP may offer good control when used, but may only be worn part of the sleep time, particularly in patients who find the side effects of oral and nasal dryness, nasal congestion, epistaxis, pressure intolerance, aerophagia, and claustrophobia intolerable.[26] Surgery is applied to the total sleep time, but may have a lesser impact on the AHI. The area under the curve of efficacy x compliance is the critical issue. With CPAP, we can look at a potentially curative treatment worn part of the time, which ultimately may be equivalent to a partial treatment (surgery) applied all of the time. The authors are in no way advocating pharyngeal surgery as a first-line treatment in OSA, rather we show that with appropriate selection criteria, in patients who have failed or reject device therapy, surgery can offer good results in terms of reduced AHI and improved symptom scores. The outcomes of this study show a reduction in $AHI_{(all\ indices)}$ but importantly also show a reduction in patient-reported symptoms as demonstrated by the reduction in the SSS and ESS.

The strengths of this article are a series of consecutive patients with prospective data collection having a defined procedure for defined OSA pathophysiology. Subjective and objective outcomes are presented to demonstrate that submucosal lingualplasty is an effective operation in a subgroup of OSA patients with macroglossia, for which there are currently few reliable or acceptable surgical options in contemporary clinical practice. The procedures were performed on consecutive patients by a single surgeon. All polysomnographic analysis was standardized and uniform. Weaknesses include the postoperative PSG rate of 67.5%. Unfortunately, we can only encourage and request patients to attend for a postoperative sleep study, and although there is no morbidity associated with this investigation there is considerable inconvenience to the patient in having to attend a hospital sleep laboratory overnight. We cannot comment on the outcomes of patients who did not undergo postoperative PSG, and of course this group, comprised of a third of the patients, may represent disgruntled failures who no longer wanted follow-up at this institution, but may also represent satisfied patients who felt they no longer needed further investigation as they felt much better. This study has not identified differences in demographic data or baseline AHI metrics in the subset of patients who did not undergo postoperative polysomnography, and a significant difference here may introduce bias to the results. The SSS pre- and postoperative scores were both generated at the time of long-term follow-up, therefore the change in values was a retrospective analysis, introducing possible bias. However, even if the baseline SSS values and change in SSS are ignored, the current long-term postoperative SSS values collected prospectively are very low, indicating good long-term control of snoring. We also acknowledge that there are other important potential OSA outcomes measurements, which would have been ideal but were beyond the scope of this article (e.g., sleep-specific quality of life, reaction time, car crash risk assessment, mortality risk).

This article described reasons that the reader should be cautious in interpreting this and other surgical series' definitions of success, as these can ultimately vary depending on the metrics used to define success. Ultimately, surgery for OSA should be judged overall on the improvement it provides to a patient's symptoms, the reduction it offers in AHI, the degree to which it is tolerated by patients, and in the context of a cost-benefit analysis. This article does not evaluate the latter criterion but offers surgical treatment as an alternative and viable treatment for OSA in situations where first-line devices have failed.

CONCLUSION

OSA is not defined solely by a metric; the diagnosis and management of this condition takes into account patient symptomatology as well as disease severity. Similarly, the definition of surgical success should be by more than just the AHI reduction alone, and other outcomes should be included in assessment of postoperative consideration (e.g., reduction of sleepiness and snoring severity). If, however, one assesses surgical success by AHI reduction alone, then one needs to be aware that different AHI scoring techniques can make a big difference to the AHI. Thus, it is crucial to ensure the pre- and post-AHI measures are by the same scoring technique.

This article showed in a carefully selected cohort that upper airway surgery for OSA was very effective, and patients treated surgically for OSA had good symptom control, but their polysomnographic improvement can be defined as very good (91.7%) or moderate (38.9%) depending on which metric of success is used. The reader is encouraged to retain a questioning view of the success rates of other published studies of OSA, and whereas the AHI is a useful surrogate of success, patient outcomes and quality-of-life data should also be incorporated markers of success.

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