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Redefining the Timing of Surgery for Obstructive Sleep Apnea in Anatomically Favorable Patients

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Objectives/Hypothesis: Healthcare remunerating agencies in North America require patients with obstructive sleep apnea (OSA) to undergo a continuous positive airway pressure (CPAP) trial before funding surgical therapy. The adherence rate of CPAP is problematic. This study's objective was to determine the proportion of surgically favorable patients who failed CPAP who subsequently benefitted from surgical therapy, and to explore consideration of surgical therapy as first-line treatment in this specific OSA subpopulation.

Study Design: This was a prospective cohort study.

Methods: Patients with moderate–severe OSA who had failed a minimum 6-month trial of CPAP were recruited. All had optimal anatomy for surgery and underwent tonsillectomy with palatoplasty ± septoplasty. Outcome measures included apnea-hypopnea index (AHI), Epworth Sleepiness Scale (ESS), and Sleep Apnea Quality of Life Index (SAQLI-E), and blood pressure. Patients were followed for 1 year.

Results: By AHI measurement, 85.7% of patients in the entire cohort were successfully treated by surgery. ESS while on CPAP was 13.7 ± 2.9, improving to 4.1 ± 2.5 after surgery. SAQLI-E scores on CPAP were 25.7 ± 5.8, improving to 10.2 ± 3.2 after surgery. Blood pressure remained elevated during CPAP but normalized after surgery. All changes were significant at $P < .001$.

Conclusions: Surgical intervention improved OSA severity as measured by the ESS, SAQLI-E, and blood pressure. These measures had not improved on CPAP. AHI improved as well. Our results suggest that certain patients with OSA may be managed more effectively with surgery than CPAP, without confounding issues of treatment adherence and with only minor surgical risk.

Key Words: Obstructive sleep apnea, uvulopalatoplasty, continuous positive airway pressure, tonsillectomy.

Level of Evidence: 2

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INTRODUCTION

Obstructive sleep apnea (OSA) is estimated to affect 3% to 9% of the general population and is well demonstrated to be a risk factor for resistant hypertension, fatal and nonfatal cardiovascular disease, neurological disease, and all-cause mortality.[1] OSA has deleterious effects on economic productivity, and is known to be a significant source of motor vehicle accidents.[2] The Public Health Agency of Canada and the Canadian Thoracic Society both have formally recognized OSA as a public health threat.[3,4] The American Academy of Sleep Medicine (AASM) has deemed OSA a disease with serious and life-threatening consequences, and concern to public health.[5]

Practice parameters published by the AASM recommend that continuous positive airway pressure (CPAP) should be considered both first-line and gold standard treatment for OSA; many other studies make similar statements.[6–9] When used as prescribed, CPAP does reduce daytime sleepiness, normalize sleep architecture, and improve numerous OSA-specific health outcomes.[10] To that end, the overwhelming majority of healthcare remunerating agencies in North America (insurance firms, government agencies, or otherwise) have adopted the stance that patients must undergo a CPAP trial before the agency will consider funding surgical therapy to treat their OSA. However, the AASM parameters also recognized that a significant proportion of patients are unable to tolerate CPAP therapy, and frequently seek alternate treatment.[6] In the long term, there continues to be an unacceptably low CPAP adherence rate for various reasons including comfort, convenience, claustrophobia, and cost.[6] A review article by Weaver and Ronald reported that up to 50% of all patients permanently abandon CPAP treatment during the first week, and 12% to 25% of the remaining users abandon CPAP at some point throughout the next 3 years.[11] Other authors have also found that the estimated overall rate of nonadherence was as high as 83% when defining CPAP

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adherence by AASM minimum acceptable usage standards.[11–13] Until recently, such adherence data were underemphasized in the CPAP literature.

Surgery for OSA has evolved substantially in recent years, with an increasing body of evidence supporting the various possible surgical options, the most common of which is the combination of palatoplasty and tonsillectomy, with tongue base, hypopharyngeal, and osseous procedures possible too. Although from both an anatomical or body habitus perspective, many patients with OSA are not suitable for pharyngeal expansion procedures; in appropriately screened patients, good-quality data have shown that surgery offers substantial and sustained long-term improvement in both sleep study indices and patient-specific outcomes.[6,9,14,15] When considering all OSA patients, it is recognized that global treatment success rates with surgery are lower than via CPAP, but this does not hold true for the subset of patients with optimal apnea-specific surgical anatomy, wherein rates of successful surgical OSA treatment are very high. Moreover, the issue of CPAP adherence has generally not been examined during these debates; to make an effective comparison, adherence must be taken into account when studying the impact on OSA of CPAP versus surgery. CPAP, a curative therapy with inconsistent adherence, can potentially be equivalent to surgery, that being a "partial" therapy with complete adherence. It is the issue of treatment effectiveness versus adherence (the relationship of the two defining success) that is at the crux of the matter. The extension of these concepts is that certain OSA patients could be considered candidates for pharyngeal expansion surgery as a first-line treatment modality, without needing a mandatory CPAP trial first.

The objective of this study was to determine the proportion of surgically favorable patients who failed CPAP and who subsequently benefitted from surgical therapy, and to explore consideration of surgery as first-line therapy in this specific OSA subpopulation.

MATERIALS AND METHODS

Study Design and Protocol

A prospective nonblinded cohort study was conducted on consecutive patients undergoing OSA surgery. Study recruitment was from January 2008 to July 2011. Study participation was voluntary, and no remuneration was offered. This project received ethics approval from Western University, and the same senior surgeon operated on all patients.

The study was designed to assess the effect of OSA surgery in a carefully screened patient population, those being patients who were both firm CPAP failures and who were also considered anatomically optimal candidates for apnea surgery. Inclusion criteria were as follows: 1) symptomatic OSA with a level 1 overnight polysomnogram taking place within 1 year of surgery; 2) moderate–severe OSA (apnea-hypopnea index [AHI] >15 or higher, no defined upper limit, with hypopnea defined in our sleep laboratory as >50% airflow reduction or a lesser airflow reduction associated with >3% oxygen desaturation or arousal), and 3) unable to adhere to CPAP (by AASM standards of 4 hours/night, 5 nights/week) over a minimum trial duration of 6 months, with continued attempts at usage being assisted by the prescribing respirologist. If nonadherence was specifically due to nasal obstruction, then corrective nasal surgery was offered, but these patients were then excluded from the study and encouraged to resume CPAP after nasal surgery. Other specific reasons for nonadherence were not tabulated for study purposes but were explored with patients by both the surgeon and prescribing respirologists. If CPAP was firmly deemed nonviable by the patient, then alternatives were offered including oral appliance therapy or surgery. If surgery was chosen, then the patient crossed over into the surgical side of the study and was further eligible for study inclusion. The Friedman clinical staging system was used to identify those patients most likely to benefit from OSA surgery[16]: only Friedman stage 1 patients (i.e., considered anatomically optimal for surgery) were included in the study population, those being patients with relatively large tonsils (grade 3–4) and a relatively wide space between the palate and tongue base (grade 1–2). Awake supine endoscopy was used to assess airway obstruction sites; drug-induced sleep endoscopy was not used in this project because it is not commonly practiced in Canada due to operative resource restrictions. Study exclusion criteria included the following: 1) age <18 or >65 years, 2) body mass index (BMI) ≥35, 3) significant tongue base contribution to the OSA as assessed via the Moore scale,[17] 4) hypertrophic lingual tonsils, 5) pregnancy, 6) diabetes, 7) craniofacial abnormalities, and 8) severe cardiovascular comorbidities (e.g., cor pulmonale, heart failure). However, hypertensive patients were included as a subgroup. In summary, the study population consisted of anatomically straightforward patients with a high preoperative chance of surgical success, but who were also known to have problems with CPAP in the setting of moderate or severe OSA. Figure 1 shows the patient flow through the study process.

Patients undergoing surgery received a bilateral tonsillectomy and a simultaneous palatoplasty variant as deemed clinically indicated (either uvulopalatopharyngoplasty [UPPP], uvulopalatal flap, or expansion sphincteroplasty). A septoplasty and turbinoplasty were performed at the same setting if clinically indicated.

Outcome Measures

Assessment of change in the pre- and postoperative AHI was considered the main study outcome measure. Other outcomes included Epworth Sleepiness Scale (ESS), Sleep Apnea Quality of Life Index (SAQLI) scores, and systolic blood pressure (SBP). We used a modified version of the SAQLI (termed SAQLI-E) in that we collected data only from section E of the tool, which refers specifically to treatment-related symptoms. such as discomfort, social stigma, financial challenges, to gauge the effect that treatment had on patient well being, whether CPAP or surgery.[18] Demographic data collected included age, gender, BMI, Friedman tonsil/palate score, smoking status, alcohol intake, other comorbidities, and postoperative complications. The outcome measures were assessed at pretreatment baseline as AHI_{base} and ESS_{base}; while on CPAP as AHI_{CPAP}, ESS_{CPAP}, and $SAQLI\text{-}E_{CPAP}$; and then at 1-year postoperatively as AHI_{postop}, ESS_{postop}, and $SAQLI\text{-}E_{postop}$. SAQLI-E data were not available at baseline (pre-CPAP initiation) as they only measure quality of life as it pertains to treatment modality. SBP was assessed at baseline, on CPAP, and after surgery as SBP_{base}, SBP_{CPAP}, and SBP_{postop}, respectively.

Statistical Analysis

An a priori sample size calculation was performed. We used the widely accepted Sher criteria[19] to define success at

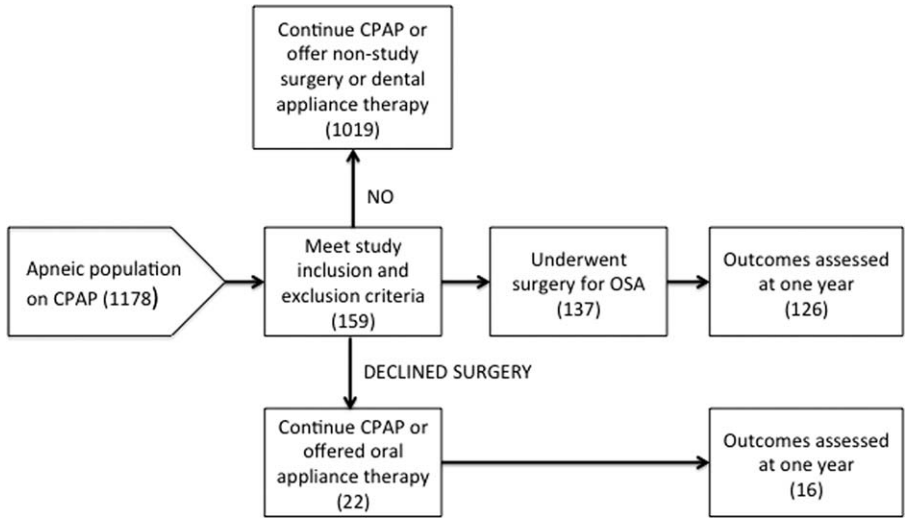

Fig. 1. Patient flow through the study showing relevant time points and number of patients. CPAP = continuous positive airway pressure; OSA = obstructive sleep apnea.

OSA surgery as being both a reduction of AHI by 50% or more and to an absolute value of l<20. Under this construct, with an α of .05 and β of .8, a minimum of 96 study subjects were required to demonstrate significance. Descriptive statistics were presented as mean with standard deviation. After confirming data as normal distribution via Komolgorov-Smirnov testing, statistical analysis was performed using one-way analysis of variance (ANOVA) testing for AHI, ESS, and SBP variables. All tests were two-tailed, and a Bonferroni-corrected P value of $<.0167$ (three comparisons) with two tails was considered statistically significant. SAQLI-E data were only available for patients on CPAP and postoperatively; therefore, these two comparisons were made as two-tailed paired t tests with significance set at $<.05$. All analyses were performed using SPSS 18.0 software (SPSS Inc., Chicago, IL).

RESULTS

Demographics and Surgical Details

Over the 3.5-year study time period, 1,178 patients were referred to the Sleep Surgery Program clinic at Western University for consultation regarding surgery for OSA. A total of 159 patients (13.5%) met study inclusion/exclusion criteria and were offered participation, of which 137 patients agreed and underwent surgery. Of these, 11 were ultimately lost to follow-up and unable to complete data collection, leaving a final study population of 126 patients (10.7%) who met all study criteria, agreed to participate in the project, underwent surgery, and were followed to study conclusion. Twenty-two patients who met study criteria declined surgery and chose to continue on CPAP but still agreed to have outcomes assessed at baseline and follow-up; six of these were lost to follow-up, leaving only 16 to assess at 1 year. Figure 1 shows the patient flow and study population numbers as subjects moved through the study process. Table I lists the relevant demographic and surgical detail characteristics of the surgical study sample. BMI did not change significantly in this group over the study duration. There was a mean time of 6.3 months between the patient being determined as CPAP nonadherent and receiving surgery.

Outcomes Assessments for Patients Who Underwent Surgery

AHI. In total, 108 patients (85.7%) were successfully treated via surgery by Sher criteria (Table II). The AHI_{base} was 47.3 ± 11.4 and decreased to an AHI_{postop} (for the entire sample) of 19.8 ± 11.1. When limited to the 85.7% of patients achieving surgical cure, this value dropped dramatically to an AHI_{postop} of 9.8 ± 5.9. In comparison, AHI_{CPAP} was 5.8 ± 5.4. The three values were significantly different on ANOVA testing at $P < .0167$. AHI_{CPAP}, however, was not adjusted for CPAP adherence; this value was simply the number reported on the laboratory CPAP sleep study, which is known to be artificially lower than what the AHI is when measured over total sleep time during the period of prescription.[11–13]

TABLE I.
Baseline Characteristics of Study Participants Who Underwent Surgery.

Characteristics	Value
Gender	
Male	107
Female	19
Age, yr	40.5 (29.2–51.3)
Mean follow-up, wk	52.9 (48–58)
BMI	30.9 (23.2–34.8)
Comorbidities, no. (%)	
Resistant hypertension	22 (17.4)
Reflux disease	78 (61.9)
Hyperlipidemia	47 (27.3)
Surgical procedures, no. (%)	
UPPP alone	34 (26.9)
UPPP + septoplasty	29 (23.0)
ES or UPF alone	42 (33.3)
ES or UPF + septoplasty	21 (16.8)

BMI = body mass index; ES = expansion sphincteroplasty; UPF = uvulopalatal flap; UPPP = uvulopalatoplasty.

TABLE II.
Outcome Measurements for the Entire Surgical Cohort.

Variable	Mean	SD	*P* Value
ESS			<.001
Baseline	14.3	3.5	
CPAP	13.7	3.1	
Surgery	4.1	2.5	
AHI			<.001
Baseline	47.3	11.4	
CPAP*	5.8	5.4	
Surgery	19.8	11.1	
SAQLI-E (x/35)			<.001
CPAP	25.7	5.2	
Surgery	10.6	3.1	
SBP†			<.001
Baseline	143.2	4.3	
CPAP	144.3	4.0	
Surgery	134.5	3.9	

*CPAP value was not adjusted for total sleep time; this is only the sleep lab reported value.

†These data reflect only the 22-patient subgroup with resistant hypertension.

AHI = apnea/hypopnea index; CPAP = continuous positive airway pressure; ESS = Epworth Sleepiness Scale; SAQLI-E = sleep apnea quality-of-life index domain E; SBP = systolic blood pressure; SD = standard deviation.

Hourly adherence data regarding CPAP usage could not be obtained consistently and therefore were not reported.

ESS. ESS_{base} was 14.3 ± 3.5, whereas ESS_{CPAP} was 13.7 ± 2.9, indicating significant sleepiness during the time of CPAP prescription, likely due to the fact that patients were having difficulty adhering to CPAP use (Table II). All patients had an improvement in their ESS score after surgery to a mean ESS_{postop} of 4.1 ± 2.5. This was significant at $P < .001$.

SAQLI-E. SAQLI-E aggregate values can range from a high (considered a very large problem) of 35 to a low (considered no problem) of 5 (Table II). $SAQLI\text{-}E_{CPAP}$ scores were a high 25.7 ± 5.8, indicating a moderate to large impaired quality of life (QOL) while on CPAP. With surgical intervention, the mean improvement for the entire cohort was to a $SAQLI\text{-}E_{postop}$ score of 10.2 ± 3.2, indicating either no problem or a small problem. This change was statistically significant at $P < .01$ and shows improved QOL relating to surgical treatment as compared to while on CPAP.

Blood pressure. In the subgroup of 22 patients with resistant hypertension, SBP_{base} was 143.2, SBP_{CPAP} was 144.3, and SBP_{postop} was 134.5 (Table II). ANOVA testing did not show any difference between SBP_{base} and SBP_{CPAP} ($P = .72$) but did reveal a significant improvement ($P < .001$) between SBP_{postop} and the other two groups.

Operative Complications

Four patients (3.1%) developed transient velopharyngeal insufficiency, all of which resolved within 1 month after surgery without the need for intervention. Two patients (1.6%) developed a post-tonsillectomy minor hemorrhage, and one patient (0.8%) a postseptoplasty hemorrhage. These latter three complications resolved via conservative measures in the emergency room without the need for further surgery.

Patients Who Met Study Criteria but Declined Surgery

In total, 22 patients met inclusion/exclusion criteria but declined surgery and chose instead to continue CPAP or trial an oral appliance. These patients were also contacted at 1 year to try and assess their outcomes. Sixteen could be reached; of these nine were still using CPAP, two were using an oral appliance fashioned by a dentist, and five were not continuing with any regular treatment for OSA. Due to the significant heterogeneity of this sample and that it was incomparable in size to the surgical arm, we chose to forgo outcomes assessments in this group.

DISCUSSION

OSA treatment guidelines mandate a CPAP trial as first-line therapy because when used as prescribed it is indeed a noninvasive curative therapy. These same practice parameters discourage or even disallow surgery as first-line therapy. Consequently, nearly all physician and hospital remunerating agencies have adopted this same position. To some caregivers the concept of cure is purely dichotomous (success vs. failure, with no spectrum between). However, this paradigm is invalid in the OSA population, where what is considered the gold standard of therapy is problematic because of high rates of nonadherence. The findings of the current study's novel structure of assessing CPAP and surgery as independent consecutive interventions in an anatomically optimal but CPAP nonadherent patient population, suggest that surgery could have been offered to this group as a primary treatment option in lieu of CPAP, rather than requiring a CPAP trial first as is currently considered standard practice in North America. In our study population of patients who had not improved during the time of CPAP prescription, over 85% of subjects were improved with surgery via all outcome measures. The study subjects were selected for surgical success; therefore, their improvement after UPPP is not surprising. However, what is striking was the relative lack of improvement while on first-line CPAP therapy, and how this stands in marked contrast to the significant betterment after surgery. Had our study cohort undergone surgery as first-line therapy, they would have been successfully treated at a much earlier stage in their disease process.

In recent years, considerable efforts have been undertaken to establish best-care practices for OSA. Examples of these efforts include two major Cochrane Collaboration reviews, published in 2008 and 2009,[20,21] and further systematic literature reviews by the National Institutes of Health Research (NIHR)[22] and the Agency for Healthcare Research and Quality (AHRQ),[23] published in 2009 and 2012, respectively. These four

reviews all focus on the evidence supporting specific management techniques for OSA, the quality of that evidence, and the knowledge gaps that remain to be filled. One of these reviews also addresses the economic efficiencies of using CPAP.[22]

As expected, the majority of analysis across these reports focuses on the use of CPAP.[20,22,23] The two reviews specifically of randomized clinical trials, conducted by the Cochrane Collaboration and the NIHR, included 36 and 48 studies, respectively, with 83% study overlap. The discrepancy in numbers of trials is largely explained, with one exception,[24] by the inclusion of studies published in 2006 or later in the NIHR review. The conclusion of these two reports,[20,22] as well as of the AHQR report,[23] are much the same: that CPAP is considered first-line treatment for OSA, but also that numerous gaps in knowledge and deficiencies in methodology persist that severely limit this conclusion. Among the most problematic issues that reviewers observed were the almost complete absence of any data on the long-term effectiveness of CPAP. For example, of the 52 distinct studies reviewed across the Cochrane and NIHR reports, all but three were of 3- months duration or less.[25–27] Numerous additional limitations were noted, such as methodological issues over sample sizes and appropriate control interventions, some of which (e.g., sham CPAP) allowed for blinded assessments, whereas others (e.g., postural therapy, medication, no active treatment) did not. Further issues pertaining to the effectiveness of CPAP as first-line therapy for OSA include the lack of any consistent improvement in measures of OSA disease symptomatology. For example, among the 23 studies reviewed by McDaid et al.,[22] in which subjects were stratified by baseline ESS, only 14 (61%) yielded a statistically significant benefit of CPAP. For the maintenance of wakefulness test, multiple sleep latency test, and daytime diastolic blood pressure, CPAP out-performed control interventions only 17%, 14%, and 14% of the time, respectively.[22] Most measures of QOL also remained unchanged, as did parameters of neurocognitive function and parameters of cardiovascular function. More recently, when statistically significant differences have been identified in cardiovascular outcomes, often they have been of negligible clinical significance (e.g., a net decrease of just 2 mm Hg in systolic blood pressure over 12 months in two studies[28,29] and of just 1.5 mm Hg in another[30]) with such effects only noted in those who used CPAP for at least 5.6 hours per night.[29] In one potentially dissenting study, SBP fell 10 mm Hg in OSA patients in heart failure; however, diastolic blood pressure did not decline significantly, and study follow-up was limited to only 1 month.[31] Further substantive issues noted in these reviews were the lack of any clear benefit of CPAP over other treatments such oral appliances and positional therapy (e.g., in the Cochrane review, relative to oral appliances, only one of six studies [17%] demonstrated any advantage of CPAP over oral appliances in terms of affecting the ESS[20]) and the absence of data evaluating subgroups of OSA patients, for whom different treatments might be more effective or efficient than others.[20,22,23]

A serious issue that was detailed in all three summary reports was the problem of poor adherence to CPAP.[20,22,23] For example, in the United Kingdom, whereas an estimated 180,000 patients are estimated to suffer from OSA, only 20,000 (11%) currently use CPAP.[32] Moreover, within the context of clinical trials, adherence with CPAP among those who agree to use it consistently falls between 70% and 80%,[20, 21] with up to 50% refusing to enter trials in which CPAP is being administered. Overall estimates of long-term adherence, including those who initially refuse or fail to initiate therapy, have been as low as 17% when adherence is defined using AASM minimum usage standards of at least 4 hours of CPAP per night.[12,13,33,34] As well, there is reason to believe that these adherence figures may be overestimates caused by inflated subject reporting. In a study by Kribbs et al., whereas 60% of subjects self-reported nightly use of CPAP for more than 4 hours per night, and for greater than 70% of nights, when covertly monitored, only 46% of subjects were objectively meeting these two benchmarks.[35] In addition, in studies in which patient preference has been assessed, oral appliances and postural therapy are almost always preferred, typically due to discomfort caused by the masks, and to drying of the mouth and nose.[27,36,37] Several attempts have been made to enhance adherence with CPAP via various modifications, including nasal devices, variable- versus fixed-pressure devices, and humidification. However, such attempts generally have failed to enhance either adherence or clinical outcomes versus traditional CPAP,[38–44] with overall adherence rates, even among participants of randomized clinical trials, continuing to fall in the 70% to 80% range or lower.[26,45]

Since 2008, several additional randomized clinical trials have been published, mostly looking at OSA subgroups, not so much in terms of disease severity, but in highly specific patient populations like Alzheimer's patients,[46] stroke patients,[47] and patients with metabolic syndrome[48] rather than those with a particular level of disease severity, varying risk levels for nonadherence, or different anatomical bases for their OSA. Most of these more recent studies fall into many of the traps of prior research, generally being short term,[36,39,40,46,49–52] failing to compare different treatment approaches, or using sample sizes inadequate to detect clinically meaningful differences.[52–55] In one larger and longer randomized trial, in which 723 non-somnolent patients with OSA were randomized either to CPAP (N = 357) or no active treatment (N = 366) over a median of 4 years of follow-up, no intergroup difference was detected in the incidence of hypertension or other cardiovascular events.[56] And in another randomized trial comparing nasal CPAP and an oral appliance over 12 months, though AHI scores improved from baseline in both treatment groups, there was no difference between them, except that more subjects withdrew from the nasal CPAP treatment arm due to side effects.[53] For all these reasons, CPAP may in fact stand on shaky ground in terms of its position as first-line treatment for all OSA patients and all OSA patient subsets.

Historically, surgery has been considered as second-rate, second-line, or salvage-only treatment for OSA. In North America, most government health agencies or insurance policies only fund surgery for OSA after a prolonged trial of CPAP has failed. Considerable research has been published assessing the effectiveness of surgery in the treatment of OSA. Although from an anatomical perspective, many patients with OSA are not suitable for pharyngeal expansion procedures; in appropriately screened patients, data demonstrate that surgery can produce substantial and sustained long-term improvements in both sleep study indices and patient-specific outcomes.[6,9,14,15,21,57] Several technically distinct surgical procedures have been attempted for OSA, so relatively few randomized studies exist evaluating any single procedure. Of the various surgical approaches, UPPP is the most often tested,[14,15,21,26,58–60] including one large, 12-month multicenter study that documented improvement in quality of life in 68 patients undergoing UPPP,[15] and another study in which 57.1% of 14 patients continued to have reduced ESS versus baseline at 7 years of follow-up.[14] However, in their meta-analysis, Aurora et al. determined that UPPP on its own was not consistently effective, and recommended that these procedures typically be paired with other procedures such as tonsillectomy or septoplasty,[6] a recommendation that the recently published results of Yaremchuk et al. support.[9]

Only two studies have directly compared surgery and CPAP in terms of effectiveness. In one randomized trial, using nocturnal oxygen desaturation events of 4% or more per hour in bed as the main outcome, 62% of nasal CPAP and 39% of primarily UPPP patients exhibited normalized oxygenation at 1 year ($P = .17$, not significant); there also was no difference in daytime somnolence, and 38% of CPAP patients had discontinued treatment.[26] The other retrospective cohort study compared mortality rates in 18,754 CPAP patients and 2,072 UPPP patients, which were 7.1% and 3.4%, respectively ($P < .001$)[61]; adjusted mortality was 31% higher ($P = .03$) in those on CPAP.

Staunch CPAP proponents argue that an AHI <5, which is considered a satisfactory treatment response with CPAP, is rarely achieved in postoperative patients. Elshaug et al. proposed that given that an AHI $\leq$10 is only achieved in roughly 30% of surgery patients,[62] surgical treatment for OSA should never be the first line.[62,63] However, given that the average CPAP patient only uses their device 60% of the time, AHI scores <5 on CPAP are, in all likelihood, an aberration relative to real-life practices. In a cleverly devised mathematical model, Ravesloot and de Vries demonstrated that, in patients with moderately severe OSA, those who achieve an AHI of 0 while on CPAP must use the device 67% to 83% of the time to achieve an average AHI <5, and those whose AHI is just 5 on CPAP must use the device 100% of the time.[64] Stuck et al.,[65] in a response to the work of Elshaug, demonstrated that even in a maximally compliant CPAP population, the average AHI achieved is no better than just under 12 (11.9), a value derived by analyzing data from 750 compliant patients on CPAP, including average AHI and time on and off CPAP over an average treatment period of 585 days. Over this period, each subject's average hours of sleep was estimated by the patients themselves (mean was 6.5 hours per night) at routinely scheduled 3- to 4-month visits, whereas hours using CPAP were recorded by the CPAP devices built-in counters (mean = 4.69 hours/night), AHI without CPAP was assigned to be the AHI at the time of initial diagnosis, and AHI on CPAP was the AHI recorded at the target CPAP pressure as noted at the time of in-lab CPAP adjustment.

Certain advantages of surgery over CPAP exist. One is the nonissue of compliance with surgical approaches, because surgery is generally a one-off event. A further advantage of the one-off component of surgery relates to costs, because the costs of CPAP, estimated in the United Kingdom as £20,000 (roughly US$30,000) per quality-adjusted life year, typically are lifelong.[22] Main et al. published a meta-analysis of 30 randomized, crossover, and other controlled clinical trials, as well as certain eligible pre- and post-treatment studies, specifically comparing the costs of nonsurgical (CPAP, mandibular advancement splints, and tongue-retaining devices) versus surgical treatment of OSA.[66] though they admitted that data were scarce, the authors estimated that, in the United Kingdom, the average cost of a UPPP procedure at the time was £1,230 to £1,550, depending on the length of hospital stay (1 vs. 2 nights) versus £220 annually for CPAP, meaning that the costs associated with CPAP would start to exceed those of surgery within 6 to 7 years. Although formal cost comparison data are not available in published format for Canadian centers, anecdotal description suggests that in Ontario, CPAP systems can cost in the region of $1,500 to $2,000 depending on the machine, type of mask, and level of service chosen by the patient. Patients incur extra costs for mask upgrades or if they use a more comprehensive plan involving assessments by the CPAP provider. In Ontario, the public healthcare system covers approximately 50% of the start-up cost, but the patient is responsible for annual maintenance costs of approximately $200 for masks and filters. In contrast, the cost in Ontario of a standard UPPP (including operating room time, nursing fees, surgeon fees, anesthetic fees, recovery room fees, and a single overnight stay) is approximately $31,00.00 as a single fee. Thus, like the United Kingdom, CPAP costs will exceed surgery after $\sim$6 to 7 years of use in Canada.

Yet another advantage of adopting a surgery-first approach in carefully screened OSA patients is the risk of CPAP withdrawal. In a recent study in which 41 patients with OSA were randomized to either CPAP withdrawal or CPAP continuation for 2 additional weeks, those withdrawn from CPAP experienced 8.5 mm Hg and 6.9 mm Hg increases in morning SBP and diastolic blood pressure, respectively, and a 6.3-bpm increase in morning heart rate, as well as elevated levels of urinary catecholamines as a proxy marker for endothelial dysfunction.[67] It is for such reasons that Sundaram et al.[21] in their Cochrane review, and Balk et al.[23] in their review of future research needs in OSA, both call for

surgical trials assessing surgery in specific patient subsets.

For patients with appropriate anatomy, surgical treatment with its associated complete adherence rate may still define a successful outcome even without formal AHI cure. In addition, surgical treatment may also lead to greater sustained overall improvement in patient-specific OSA outcomes. Our study sample cure rate of 85.4% compares favorably with the original Friedman publication indicating a cure rate of 80.6% in stage 1 patients.[16] The subgroup of patients we studied in this project was considered anatomically optimal for surgery in terms of having large tonsils, a favorable oropharynx relationship, and relatively low BMI. In the original paper on their staging system, Friedman's group determined that roughly 21.1% of OSA patients could be classified as stage 1 patients.[16] This estimate has been considered high by other authors, but the literature does point to a fairly consistent range of 10% to 13% of adult OSA patients as meeting stage 1 criteria. Although the proportion is not large, the absolute number of patients worldwide meeting this designation would still run into the millions. Such a large number carries significant medical, resource, and societal implications by extension of the findings in the current study. It is well known that untreated OSA sufferers use more healthcare resources than non-OSA patients,[2] and are also at higher risk for being involved in motor vehicle accidents.[68,69]

Although ideally, all patients could be successfully treated via noninvasive techniques, that is manifestly not the case in reality. To be clear, we do not advocate that surgery is the best or only solution to OSA either. However, we do suggest that in patients such as those in our study sample (who were anatomically optimal candidates for a surgery that carries a known high success rate), it does not make scientific or health-economic sense to delegate surgery to second-line therapy.

Untreated obstructive sleep apnea is known to decrease long-term survival due to the comorbidities associated with it. In our study, we have demonstrated a novel finding of OSA surgery successfully treating hypertension. Although patients did not become normotensive after surgical therapy, their SBP did lower and become nonresistant. Cardiovascular outcomes are notably lacking from the surgical OSA literature; however, in this study we have demonstrated in a small subset of our population that surgical therapy had a marked improvement on blood pressure status that did not occur during the time of CPAP prescription. In the paper by Weaver and colleagues[61] showing the survival benefit of surgery over CPAP, one of the reasons postulated for this unexpected finding was thought to again be due to the issue of nonadherence to CPAP therapy relative to the permanence of successful surgery in appropriate patients. Patients more adherent to therapy had better cardiovascular outcomes in the long run.

This study does have limitations. It was powered to be large enough to ensure the validity of the results, but it would be beneficial for a still larger study to be performed from a multicenter perspective to ensure the results are both reproducible and applicable to a broader geographic population. Only 22 hypertensive patients were included, and although our finding of blood pressure reduction after surgical therapy is compelling, this relatively small specific subset of the data is underpowered to make larger conclusions than that. Studying a more purely hypertensive population would be of value in future studies. Longer-term data assessing sustainability of the surgical improvement over years following surgery would be important. Although our study's follow-up length of 1 year is on the longer end of the surgical literature spectrum, this does not obviate the need for further follow-up data. Patients undergoing surgery for sleep apnea in this study brought with them an inherent selection bias as well in that they were unable to be adherent to CPAP and therefore were preprogrammed to have a better subjective outcome with any other therapy. Finally, the highly selected nature of our patients may call into question external generalizability. However, we make no statement that surgery should always replace CPAP as first-line therapy; CPAP remains a primary therapeutic modality for OSA in many circumstances. Rather, our goal was to demonstrate that in a specific OSA patient subpopulation, those being the ~10% proportion of patients considered anatomically optimal, that surgery could potentially have been offered as first-line therapy in lieu of CPAP, instead of being considered as either inferior therapy or mandated by practice guidelines and administrative policies to second-line treatment.

An important direction for future research would include a controlled comparison of CPAP versus surgery in patients with favorable anatomy to more directly contrast the results of these two interventions. Another important question to answer would be concerning QOL outcomes in regard to OSA therapy. In this study, the SAQLI-E was administered as a QOL measure regarding treatment effect on QOL, and showed that in our study sample QOL was impaired on CPAP but improved after surgery. In the modern era of evidence-based medicine and increasingly limited economic resources, more and more reimbursement decisions use QOL outcomes to judge therapy effectiveness and appropriateness. OSA is a disease where medical outcomes (e.g., AHI) frequently do not correlate well with QOL outcomes; the literature is beginning to focus on which is the more valid measure in regard to measuring success of OSA therapy. Although our study suggests that QOL in OSA can be improved after surgery, our markers were either nonspecific (ESS) or treatment-related (SAQLI-E). It would be useful if an OSA-specific QOL marker could be developed and tested.

CONCLUSION

In our population of OSA patients who were unsuccessfully treated with CPAP but were anatomically optimal surgical candidates, surgical intervention for OSA significantly improved disease severity as measured by AHI, daytime sleepiness as measured by the ESS, and treatment-related QOL as measured by the SAQLI-E. In

a subset of these patients, blood pressure as a marker of cardiovascular dysfunction also improved after surgery, whereas it did not improve during the duration of CPAP prescription. The data from our study suggest that in appropriately screened patients with OSA, healthcare professionals and insurance agencies could consider altering their treatment algorithms to offer surgical intervention as an option for first-line therapy instead of requiring a mandatory CPAP trial first before offering surgery. For this anatomical subset of the OSA patient population, the scientific evidence does not support the assertion that a CPAP trial must take place before considering surgical intervention. Within the limits of the study's methodology, our results indicate that for suitable patients with moderate or severe OSA who have favorable anatomy, their disease can potentially be managed more effectively with surgery than CPAP, without confounding issues of treatment cost or adherence, and with only minor surgical risk. Were surgery to be offered as an option for first-line therapy, a potential for cost savings also exists.

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