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ORIGINAL ARTICLE

Combined Expansion Pharyngoplasty and Anterior Palatoplasty for the Treatment of OSA

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Abstract To evaluate the success rates of combined Expansion Sphincter Pharyngoplasty and the Anterior Palatoplasty in the treatment of OSA. A two center prospective series of 73 patients with OSA. All patients were >18 years old, retro-palatal obstruction, concentric velo-pharyngeal collapse, BMI < 33, Friedman clinical stage II, with all grades of AHI. The procedure involved the anterior palatoplasty, tonsillectomy and expansion sphincter pharyngoplasty with or without nasal surgery. There were 68 men and 5 women, the mean age was 46.8 years old (range of 25–67 years), mean BMI was 25.5 (range of 20.3–31.2). All patients had pre-operative and post-operative PSG. The AHI improved in all patients, mean AHI improved from 26.3 ± 17.7 to 12.6 ± 5.8 ($p < 0.001$). There were 20 mild OSA, 33 moderate OSA and 20 severe OSA patients. Twenty-three patients had pre-operative DISE, and 61 patients had nose/palate surgery, while only 12 had palate surgery alone. The overall success rate (50 % reduction and AHI < 20) was 86.3 %. The mean snore scores (VAS) improved from 8.8 ± 1.2 to 2.0 ± 1.3 ($p < 0.001$). The mean Epworth score improved from 11.5 ± 2.2 to 2.9 ± 2.1 ($p < 0.001$). Lowest oxygen saturation also improved in all patients. Subjectively, all the patients felt less tiredness. Pre-operative DISE assessment did not seem to confer any advantage over the patients who had no pre-operative DISE ($p = 0.027$), and patients who had nose/palate surgery seemed to have better success rates compared to those who only had palate surgery ($p = 0.081$). This combined technique has been shown to be effective in selected group of OSA patients. *Level of evidence* IV.

Keywords Expansion sphincter pharyngoplasty · Anterior palatoplasty · Obstructive sleep apnea

Introduction

Obstructive sleep apnea is due to the collapsibility of the upper airway during sleep. These collapsible soft tissues when subjected to negative pressure within the upper airway may lead to complete or partial obstruction of the upper airway leading to cessation of breathing, increased sympathetic activity, increased blood pressure and hypoxaemia. Collapse of the upper airway is often multilevel, at the level of the velopharynx, the base of tongue, and/or the lateral pharyngeal walls. Many patients with obstructive sleep apnea (OSA) have bulky thick lateral pharyngeal walls that contribute to the collapse and obstruction of the upper airway at the velopharyngeal level. These areas of collapse should be addressed, if one is aiming to relieve the patient of the apneas. Hence, upper airway evaluation is crucial in the assessment of the anatomical site of obstruction. The level of collapse can be assessed using the Muller maneuver noted with the fiberoptic flexible nasopharyngoscopy. The Muller maneuver is usually graded on a 5 point scale, 0–4 [1]; Terris et al. [2] described

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the Muller maneuver finding based on 3 levels, soft palatal collapse, lateral pharyngeal wall collapse and base of tongue collapse. Lateral pharyngeal muscle wall collapse has been demonstrated to be important in the pathogenesis of OSA in imaging studies [3, 4]. This lateral wall collapse can also be documented with drug induced sleep endoscopy (DISE). Many patients with OSA have significant lateral wall collapse; in addition, OSA patients may also have concentric collapse (i.e. circular collapse, both anterior posterior and lateral pharyngeal wall collapse).

The lateral pharyngoplasty, first described by Cahali [5], was aimed at addressing the lateral pharyngeal wall collapse in patients with OSA. The procedure showed promising results; however, many patients had dysphagia post-operatively. Pang and Woodson, in their randomized controlled clinical trial, described the Expansion Sphincter Pharyngoplasty which demonstrated good encouraging clinical results [6]. It was Orticochea [7] who first described the construction of a dynamic muscle sphincter, by isolating the palatopharyngeus muscle, and apposing them bilaterally superiorly in the midline, for treatment of velopharyngeal incompetence in patients with cleft palates. The modified Orticochea procedure was described by Christel et al. [8], the procedure differed by isolating the palatopharyngeus muscle bilaterally, apposing them more superiorly and closing the lateral pharyngeal defects with Z-plasty sutures. Utilizing these procedures, the Expansion Sphincter Pharyngoplasty was introduced.

The palatal stiffening operation was first introduced by Ellis [9] (this involved stripping of a small area of uvular and palatal mucosa) and modified by Mair [10]. Both techniques had promising results, although it produced a stellate and puckered scar on the soft palate that resulted in tenting and pulling of the lateral pharyngeal walls medially, and therefore narrowing of the lateral distance between the tonsillar pillars laterally. These anatomic manifestations might explain why some patients did not have much benefit from the procedure. Pang et al. [11] described the modified cautery assisted palatal stiffening operation (CAPSO) technique done under local anaesthesia (LA). This technique had showed encouraging results for patients with snoring and mild OSA [11]. The modified CAPSO technique was renamed as the Anterior Palatoplasty in 2009, as the technique involved the anterior surface of the soft palate primarily [12].

We present the combined expansion pharyngoplasty and anterior palatoplasty in the management of patients with OSA.

Methods and Materials

This was a non-randomized prospective dual-center trial of 73 consecutively collected patients. Patients were evaluated in the snoring/sleep subspecialty clinics in both Sant'Orsola-Malpighi University Hospital, Bologna, Italy and Asia Sleep Centre, Singapore. Surgical procedures were performed by the authors K. P. P and O. P.

The inclusion criteria was age >18 years, BMI < 33, tonsil size grade 1 and 2, elongated uvula, Friedman clinical stage II, minimal or no base of tongue collapse (<25 %) as seen on Muller's maneuver and/or drug induced sleep endoscopy (DISE), retropalatal obstruction, concentric collapse noted on Muller's maneuver and/or drug induced sleep endoscopy (DISE), no previous oronasal surgical procedures and all AHI. The study protocol and methodology was reviewed and approved by the hospital Ethics Committee/Institutional Review Board (IRB).

All patients underwent a comprehensive clinical assessment including a thorough physical examination, nasoendoscopy, and an overnight polysomnography (PSG). Patients completed the Epworth Sleepiness Scale (ESS) and a visual analogue scale (VAS) for snoring before and after surgery. The sleep partner completed a similar scale for snoring. The patient also completed a VAS for pain on postoperative days 1, 3, 7 and 14. Examination included height, weight, neck circumference, body-mass index (BMI), and blood pressure, and an endoscopic assessment of the nasal cavity, posterior nasal space, oropharyngeal area, soft palatal redundancy, uvula size and thickness, tonsillar size and Mallampati grade. Flexible nasoendoscopy was performed for all patients, and collapse during a Mueller's maneuver was graded for the soft palate, lateral pharyngeal walls and base of tongue on a 5 point scale [6]. Patients who complained of nasal obstruction and/or persistent runny nose with clinical endoscopic findings of either turbinate hypertrophy, septal deviation and/or nasal polyps were offered nasal surgery at the same sitting as the palate surgery. The nasal surgery were mainly a septoplasty and/or bilateral radiofrequency turbinate reduction. There were no drop-outs or withdrawals in this study.

Drug induced sleep sedated endoscopy (DISE) was performed for patients who were willing to undergo the sedated examination and who could afford the financial costs involved. The procedure was performed in the operating room, with the presence of an anesthesiologist. Patients were given only intravenous propofol in a gradual titrated dose, to a point where the bispectral electro-encephalogram showed a reading of around 40–60 and/or there was significant airway obstruction (whichever event occurred first). The flexible naso-endoscopy was introduced into the nose and the pattern of collapse of the upper airway was noted and recorded.

Outcome measures included subjective improvement in snoring based on the VAS and improvement in sleepiness as indicated by the Epworth scale. Objective changes presented by the polysomnographic findings. Reduction of

at least 50 % of the pre-procedure AHI and post-procedure AHI below 20 was deemed a success.

Surgical Technique

The Expansion Sphincter Pharyngoplasty (ESP) procedure was first introduced by Pang and Woodson [6]. Pang and Woodson described the surgical procedure as basically a bilateral tonsillectomy, palatopharyngeus muscle rotation flap that is antero–supero-laterally rotated with a Fig. 8 suture, through the muscle bulk itself, with a vicryl 4/0 round body needle. This palatopharyngeus muscle is isolated and left with its posterior surface partially attached to the posterior horizontal superior pharyngeal constrictor muscles. Sufficient muscle has to be isolated in order to mobilize the muscle and allow the suturing of the muscle with the vicryl suture. The original description had a supero-lateral incision made on the anterior pillar arch bilaterally, identifying the arching fibers of the palatoglossus muscles. The palatopharyngeus muscle is then attached to these arching fibers of the soft palate anteriorly with a Fig. 8 suture, through the muscle bulk itself, with a vicryl 4/0 round body needle. A partial uvulectomy may be performed depending on the size and bulk of the uvula. The anterior and posterior tonsillar pillars are then apposed with vicryl sutures.

There have been some modifications of the expansion pharyngoplasty technique, namely the Functional Expansion Pharyngoplasty [13, 14] and the Modified Expansion Pharyngoplasty [14], both being similar and fundamentally alike (with the crucial isolation of the palatopharyngeus muscle and its rotation antero–supero-laterally). Both techniques describe the use of a tunneling method of mobilizing the palatopharyngeus muscle antero–supero-laterally through an incision made on the anterior surface of the soft palate, just medial to the last upper molar on their respective sides [13, 14].

On the anterior surface of the soft palate, the anterior palatoplasty is performed (usually using diathermy/radiofrequency/coblation), followed by supero-lateral cuts (para-uvular cuts) on either side of the uvula (especially if there were very prominent posterior and/or anterior palatal arch webbing), through both soft palatal arches. The anterior palatoplasty, as described by Pang et al. [11, 12], involves a horizontal rectangular strip of mucosa removal from the soft palate (about 40–50 mm in length by 7–10 mm in width); down to the muscle layer. Hemostasis may be achieved with electrocautery. The horizontal stripped area on the soft palate would be sutured with Vicryl 4/0 round body curved needle. A minimum of fifteen to twenty sutures are used to appose the wound edges (while suturing, the entire soft palate would be transposed anteriorly and superiorly). Combining these two techniques would open up the concentric collapse of the velo-pharyngeal area.

All analyses were performed using SPSS 23.0 with statistical significance set at $p < 0.05$. The pre-post comparisons on the outcome measures were evaluated using paired T test when normality assumptions were satisfied otherwise Wilcoxon signed rank test was used.

Results

There were 68 men and 5 women (22 Caucasian and 51 Asian), the mean age was 46.8 years old (range of 25–67 years), mean BMI was 25.5 (range of 20.3–31.2). There were a total of 73 combined expansion pharyngoplasty and anterior palatoplasty procedures performed in these 73 patients, 61 nasal procedures (53 septoplasties and 60 radiofrequency bilateral turbinate reductions); 12 patients had only palate surgery performed alone.

The mean pre-operative BMI reduced slightly from 25.5 to 24.2 post-operative; this was not statistically significant. The AHI improved in all patients, mean pre-operative AHI improved from 26.3 ± 17.7 to 12.6 ± 5.8 post-operatively ($p < 0.001$). The RDI also improved in all patients, with the mean pre-operative RDI improving from 29.4 ± 16.4 to 15.6 ± 6.7 post-operatively ($p < 0.001$). Lowest oxygen saturation also improved in all the OSA patients, from a mean pre-operative 83.8 ± 8.2 to 89.0 ± 3.6 ($p < 0.001$) (Table 1). There were 20 patients with mild OSA, 33 patients with moderate OSA and 20 severe OSA patients. Twenty-three patients had pre-operative (drug induced sleep endoscopy) DISE, while 50 patients did not have any DISE performed. There were 61 patients who had nose/-palate surgery, while only 12 patients had palate surgery alone.

The respective success rates based on the severity groups mild, moderate and severe were 90, 67 and 85 % respectively (Table 2), the difference in these success rates

Table 1 Showing the pre-operative and post-operative mean parameters of the 73 patients ($p < 0.001$)

N = 73	Pre-op	Post-op
BMI	25.5	24.2
AHI	26.2	12.6
RDI	29.4	15.6
LSAT %	83.8	89.0
Snore VAS	8.8	2.0
ESS	11.5	2.9

N total number in study, *BMI* body mass index, *AHI* apnea hypopnea index, *RDI* respiratory disturbance index, *LSAT* lowest oxygen saturation, *VAS* visual analogue scale, *ESS* epworth sleepiness scale

Table 2 Showing patients categorized based on OSA severity, statistically not significant ($p = 0.068$)

	Patient (N)	N/success rate (%)
Mild OSA	20	18 (90 %)
Moderate OSA	33	22 (67 %)
Severe OSA	20	17 (85 %)

Table 3 Showing the success rates of patients with or without pre-op DISE ($p = 0.027$)

	Patient (N)	Success rate (%)	Change in BMI ($p < 0.001$)
Pre-op DISE	23	73.9	0.5 increase
Pre-op no DISE	50	88	6.7 decrease

The difference was noted in these two groups, but may be attributed to the drop in BMI in the No DISE group of 6.7, compared to the DISE group where there was a gain of 0.5 ($p < 0.001$)

Table 4 Showing that patients with both nose and palate surgery had a slight advantage in success rates compared to those who had palate surgery alone, however

	Patient (N)	Success rate (%)
Nose/palate surgery	61	88.5
Palate surgery	12	75

This was not statistically significant ($p = 0.081$)

based on AHI criteria were not statistically significant. The 23 patients who had pre-operative DISE performed had a success rate of 73.9 %, while the 50 patients who did not have pre-operaive DISE, had a success rate of 88 % (Table 3) ($p = 0.027$). This difference noted in these two groups may be attributed to the drop in BMI in the No DISE group of 6.7, compared to the DISE group where there was a gain of 0.5 in BMI ($p < 0.001$). Combined nose and palate surgery in 61 patients seemed to confer a slight advantage in terms of success rate at 88.5 %, compared to 75 %, patients who only had palate surgery alone (Table 4), however, this was not statistically significant ($p = 0.081$).

The mean snore scores (VAS) improved from 8.8 ± 1.2 to 2.0 ± 1.3 ($p < 0.001$). The mean Epworth score improved from 11.5 ± 2.2 to 2.9 ± 2.1 ($p < 0.001$). Subjectively, all the patients felt less tiredness. The overall success rate (with the criteria of 50 % reduction of pre-operative AHI and post-operative AHI < 20) was 86.3 %, with a mean follow up time of 6.6 months, median follow up at 5.7 months and a range of 3–30 months.

The mean operative time was 39.8 min (range 25–57 min). There were no complications; specifically, there were no patients with velopharyngeal incompetence, oro-nasal fistula, or swallowing difficulties; there were no primary hemorrhage, however, there were 3 patients who had secondary bleeding (between 9 and 13 post-operative day) from the right tonsillar bed, whom did not require any surgical intervention.

Pain was the most common complaint. The procedure itself was painless (as it was performed under general anaesthesia); however, the VAS pain score revealed that most patients experienced most pain that peaked between 6 and 9 days after surgery.

There were no statistically significant improvements in the proportion of rapid-eye movement (REM) sleep noted post-operatively. None of the patients suffered worsening of their AHI.

Discussion

The expansion sphincter pharyngoplasty was inspired by and modified from the Orticochea [7] procedure and the lateral pharyngoplasty, described by Cahali [5]. The principle of this technique is to de-bulk and isolate the palatopharyngeus muscle (the main part of the lateral pharyngeal wall bulk) and rotate this muscle supero-anterolaterally, in order to create the lateral wall antero–latero-superior tension and reduce the bulk of the lateral pharyngeal walls. The key is to not completely isolate the muscle into a tube and rotate it, but, instead, to keep part of its fibrous/fascial attachment to the superior pharyngeal constrictor muscle, so as to create the essential tension and pull supero-anterolaterally. A complete or partial uvulectomy may be performed together with this procedure (this would depend on the patient's uvular length and tissue redundancy). The functional and the modified technique of the expansion pharyngoplasty procedure are fundamentally the same; the palatopharyngeus muscle is rotated the same direction with or without the use of a tunneling method deep to the arching fibres of the anterior soft palate muscles.

In 2000, Mair et al. [10] documented a 77 % success rate for snoring reduction in 206 patients (a 1 year follow up) who underwent the cautery-assisted palatal stiffening operation (CAPSO). Pang et al. [11] modified the CAPSO technique and had showed encouraging results in a small group of patients with snoring and mild OSA. The modified CAPSO technique was a combination the laser assisted uvulopalatoplasty (LAUP) [15] technique first described by Kamami and simple horizontal stripping of the soft palatal mucosa (similar to the CAPSO). Kamami et al. had 417 snorers who underwent LAUP and found a reduction of snoring in 95 % of the patients, after 1 year. Most authors report modest improvement after LAUP for patients with mild OSA [9, 10, 15]. By combining the use of cautery

with the principles of the laser palatoplasty technique and the creation of a horizontal denuded mucosal strip on the soft palate, with the suturing/closure of this horizontal strip, this technique is able to move the soft palate anteriorly and superiorly, while opening up the anterior-posterior velopharyngeal space. This technique is aimed at opening up the retropalatal area by transposing the soft palate anteriorly; this is similar to advancing the entire palate forwards, as with the Woodson's transpalatal advancement pharyngoplasty [14], however, without the bone surgery, and with less resulting morbidity and a much lower risk of oro-nasal fistula.

In 2007, Pang et al. [6] had showed an 82.6 % success rate (with 50 % reduction of pre-operative AHI and AHI < 20) in their randomized controlled clinical trial. Vicini et al. in their perspective multi-level sleep apnea surgery with palate and trans-oral robotic surgery (TORS) tongue base resection, showed that their initial post-operative data (when they used the traditional uvulopalatopharyngoplasty technique with the trans-oral tongue base resection) was only fair, with a mean post-operative AHI of 19.8 ± 14.1 compared to the expansion pharyngoplasty and the trans-oral robotic tongue base resection, which yielded a post-operative AHI of 9.9 ± 8.6; Vinci et al. [16] had maintained the 2 groups controlled for BMI, gender, age, pre-operative AHI and volume of tongue base tissue removed. Carrasco et al. had demonstrated in 53 patients who had moderate to severe OSA (mean pre-operative AHI 41.9 ± 24.3), that the expansion pharyngoplasty (pre-operative AHI 27.7 ± 7.5 to post-operative AHI 6.5 ± 5.2) had better results compared to the traditional uvulopalatopharyngoplasty (pre-operative AHI 47.3 ± 27.1 to post-operative AHI 12.0 ± 7.1) [17]. The authors had also showed that the success rate (with 50 % reduction of pre-operative AHI and AHI < 20) of the expansion pharyngoplasty was 90 % [17]. Ulualp et al. [14] performed the modified expansion pharyngoplasty technique on 50 matched children with severe OSA. They demonstrated that the success rate of the modified expansion pharyngoplasty technique group for a post-operative AHI < 5 was 80 %, while compared to traditional adeno-tonsillectomy group for a post-operative AHI < 5 was only 60 % [14]. Sorrenti and Piccin [13] demonstrated in 85 patients with OSA, who had the functional expansion pharyngoplasty technique done, a reduction from pre-operative mean AHI 33.3 to post-operative mean AHI 11.7; and an encouraging success rate (with 50 % reduction of pre-operative AHI and AHI < 20) of 89.2 %.

Pang et al. had demonstrated (with the anterior palatoplasty) in 77 patients with OSA, with a 3 year follow up, that the AHI had improved, from 25.3 ± 12.6 to 11.0 ± 9.9 ($p < 0.05$) [12]. Their overall success rate (reduction of at least 50 % of the pre-procedure AHI and post-procedure AHI below 20) for this OSA group was 71.8 % (at mean 33.5 months, median follow up at 31 months and a range of 29–39 months). In these 77 OSA patients, the snoring VAS reduced from 8.4 (range 7.5–9.1) to 2.5 (range 1.0–4.6) at about 30 months postoperative [12]; the Epworth sleepiness scale had similarly decreased from 16.2 (range 8–20) to 7.9 (range 5–13) postoperatively ($p = 0.05$) [12].

Uniquely, both the expansion pharyngoplasty and the anterior palatoplasty technique are performed in different OSA patients, based on their pattern of velo-pharyngeal collapse and obstruction (the expansion pharyngoplasty for lateral pharyngeal wall obstruction and the anterior palatoplasty for antero-posterior obstruction of the velo-pharynx). On their own, as reviewed above, they have fairly promising and encouraging results for these specific patients; we employed these 2 techniques in combination for patients with concentric collapse (both antero-posterior and lateral wall collapse at the velo-pharynx).

These series of 73 OSA patents were carefully selected and included based on a stringent inclusion criteria, specifically, they had fairly low BMI (<33), tonsil size grade 1 or 2, Friedman clinical stage II and had concentric retro-palatal collapse, with absent tongue base obstruction. The improvements (in the entire group) in sleep parameters, namely AHI, RDI and lowest oxygen saturation were both clinically and statistically significant. The slight decrease (as a whole group) in pre-operative to post-operative BMI was not statistically significant, and statistically speaking could not have affected the outcome. Perhaps due to the relatively small numbers in this study, we note that the success rates were better in the patients with mild and severe OSA, and also note that this was not statistically significant ($p = 0.068$) (Table 2). Comparing the patients who had pre-operative DISE assessment with the group of patients who did not have pre-operative DISE assessment, the results showed that pre-operative DISE conferred no advantage in terms of success rate ($p = 0.027$); however, there was a statistically significant decrease in the BMI for the group who had no DISE assessment ($p < 0.001$) (Table 3), hence, the apparent improvement in results might be due to the BMI decrease. There also appeared to be have a better success rate in patients who had both nose and palate performed compared to those patients who had only palate surgery done ($p = 0.081$).

We acknowledge the limitations of this study, in that the patient numbers were not large, there were only 2 sleep centers involved, most patients were Asian, and not all patients had a drug-induced sleep endoscopy done; moreover, the mean follow up time was only 6.6 months.

We present this first study of 73 OSA patients with concentric velo-pharyngeal collapse who underwent combined expansion pharyngoplasty and anterior palatoplasty with very encouraging results.

Conclusion

Overall this is an important case series on the combination of expansion pharyngoplasty and the anterior palatoplasty technique, as the field of sleep apnea surgery progresses, and the understanding of sleep medicine/airway evaluation improves, sleep surgeons need to understand that there are better surgical options for the treatment of palatal collapse (especially lateral wall collapse based on validated upper airway evaluation) than the traditional uvulopalatopharyngoplasty (which has been shown to have poorer success rates [18]); moreover, combining these techniques are also safe, anatomically sound and have low complications with promising results.

Author contribution KPP, OP conceived the study, collected the patients and performed the surgeries, wrote the article. KAP, EBP, BWR—wrote the article, results, conclusion and methodology. CYH—performed the statistical analysis and wrote the statistical section.

Compliance with Ethical Standards

Conflict of interest The authors all declare that they have no competing interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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