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Various combinations of velopharyngeal and hypopharyngeal surgical procedures for treatment of obstructive sleep apnea: Single-stage, multilevel surgery☆,☆☆

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ABSTRACT

Objective: The aim of this study was to investigate the safety and outcomes of velopharyngeal surgeries combined with hypopharyngeal surgeries as single-stage interventions for treatment of obstructive sleep apnea (OSA).
Methods: Retrospective analysis of operated patients. The velopharyngeal surgical interventions were uvulopalatal flap, anterior palatoplasty, expansion sphincter pharyngoplasty, transpalatal advancement pharyngoplasty, Cahali lateral pharyngoplasty, Z-palatoplasty, and modified uvulopalatopharyngoplasty. The hypopharyngeal surgical interventions were tongue base suspension, mucosal sparing partial glossectomy, genioglossus advancement, mandibulohyoid suspension, thyrohyoid suspension, and epiglottoplasty.
Results: Forty-one patients were enrolled after inclusion and exclusion criteria. The evaluation of symptoms and polysomnographic findings were performed preoperatively and at a minimum of 3 months postoperatively. The mean age was 42.17 ± 9.50 years and the mean follow-up time was 6.8 ± 6.0 months. After single-stage multilevel surgery, the mean apnea hypopnea index (AHI) improved from 29.13 ± 15.87 events/h to 14.28 ± 16.14 events/h ($p < 0.001$). According to the classical definition of success criteria (>50% reduction in AHI and postoperative AHI < 20 events/h), the surgical success rate was 56%, with cure of OSA (AHI < 5 events/h) in 41% of study population. The combined surgeries also improved Epworth scores, snoring scores, and respiratory parameters significantly (in all $p < 0.05$). The major complications were bleeding requiring re-admission in surgery room and severe tongue base edema which regressed by steroid administration. The minor complications were pain, difficulty in swallowing, velopharyngeal insufficiency, regurgitation, minor bleeding, and occlusion disorder. The mean postoperative period to beginning of normal feeding was 1.81 ± 1.01 days. The percentage of pain, the number of patients with major bleeding, and the need for patient-controlled analgesia were higher in patients undergoing tissue resection/ablative hypopharyngeal procedures. The mean postoperative period to beginning of normal feeding was shorter in patients undergoing suture/repositioning hypopharyngeal procedures.
Conclusion: According to outcomes of this study, OSA patients with multilevel obstructions can benefit from combined surgeries for velopharyngeal and hypopharyngeal regions at the same operation stage, without experiencing persistent complaints. It is promising that, despite multiple levels of obstruction was operated at single-stage, airway safety was preserved in all patients.

1. Introduction

Obstructive sleep apnea (OSA) is characterized by repetitive episodes of partial or complete upper airway collapse during sleep. It is associated with increased risk of cardiovascular morbidity and impairs the quality of life due to excessive daytime sleepiness [1–3]. To solve this collapse, continuous positive airway pressure (CPAP) treatment remains as the first choice of treatment modalities [4]. However, remarkable number of patients cannot tolerate CPAP [5,6], and surgical treatment becomes an alternative.

Mainly, there are two potential dynamic obstruction sites in the upper airway: velopharyngeal and hypopharyngeal regions. We know that the primary site of airway obstruction is at the level of the palate, in 50%–80% of OSA cases [7,8]. However, OSA is usually caused by multilevel obstructions, hence single surgical interventions aiming to correct only velopharyngeal region cannot eliminate all of the obstructions through the upper airway. In case of multilevel obstructions, multilevel

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surgery should be performed which can be applied as a single-stage or multi-stage. In 1986, Riley et al. have first demonstrated multilevel surgery for OSA patients with multiple obstructions by using combined maxillary, mandibular, and hyoid advancement [9]. After that, multilevel reconstruction surgeries performed by many surgeons have showed improved outcomes in relieving OSA. Today, multilevel surgical approach for OSA is accepted as a more standard treatment method than before [10–15].

Although multilevel surgery for OSA has been increasingly common, the safety of concurrent surgeries is still a question mark in the minds. Major concerns regarding multilevel OSA surgery are about multiple levels of operation sites through the upper airway, which may increase risk of airway collapse and cause more morbidities and complications such as pain, bleeding, difficulty in swallowing, etc. The aim of this study was to assess polysomnographic outcomes and complication rates of patients who underwent both velopharyngeal and hypopharyngeal surgery as a single-stage multilevel surgical intervention for treatment of OSA.

2. Materials and methods

2.1. Study protocol and patients

The patients with OSA, who underwent velopharyngeal and hypopharyngeal surgeries as a single-stage, multilevel surgery between 2009 and 2015, were included after follow-up charts review. The diagnostic work-up consisted of patient history, physical examination, and a full overnight PSG. All patients in this study were whom CPAP therapy had been offered firstly, but they had refused or terminated the CPAP therapy for any reason. Each patient underwent different combinations of OSA surgeries, but did at least one velopharyngeal and one hypopharyngeal surgery. Patients were operated on by the same surgery team (M.G., T.A., O.K., M.B.) who follow the same operative techniques. The patients were excluded if they; [1] were previously operated OSA patients, [2] had no description of preoperative or postoperative PSG data, [3] underwent multi-stage OSA surgeries, or [4] underwent any additional nasal or pharyngeal surgery or CPAP therapy before postoperative PSG.

2.2. Surgical procedures

The type of the surgery was decided according to patients' clinical findings, anthropometric and anatomic characteristics, and endoscopic examinations. Tonsil grade, Mallampati score, modified Muller's maneuver, retropalatal collapse pattern, and hypopharyngeal obstruction were evaluated. Also, some of the patients underwent drug-induced sleep endoscopy (DISE) to confirm the decision of what type of surgical intervention will be performed.

In each patient, the velopharyngeal surgery was performed first, and then the hypopharyngeal surgery was performed. The velopharyngeal surgical interventions were uvulopalatal flap (UPF), anterior palatoplasty (AP), expansion sphincter pharyngoplasty (ESP), Cahali lateral pharyngoplasty (CLP), transpalatal advancement pharyngoplasty (TPAP), Z-palatoplasty (ZPP), and modified uvulopalatopharyngoplasty (modUPPP). The UPF was performed as described by Powell et al. [16]. The AP was performed as described by Pang et al. [17]. The ESP was performed as Pang and Woodson have described and then have modified with "tunnel method" [18,19]. The CLP was performed as described by Cahali [20]. The TPAP was performed as described by Woodson and Toohill [21], but using the "propeller incision" that was described by Shine and Lewis [22]. The ZPP was performed as described by Friedman et al. [23]. The modUPPP was performed as shown by Li et al. [24].

The hypopharyngeal surgical interventions were tongue base suspension (TBS), mucosal sparing partial glossectomy (MSPG), genioglossus advancement (GGA), epiglottoplasty, mandibulohyoid suspension (MHS), and thyrohyoid suspension (THS). The MHS and THS were performed as described by Riley et al. in 1984 and in 1994, respectively [25,26]. The MSPG was performed as Badi and Woodson have introduced [27]. The TBS was performed as described by Omur et al. [28]. The GGA was performed as described by Riley and Li [29]. Epiglottoplasty was performed using the coblation.

2.3. Primary outcomes

As the primary outcomes, AHI levels were compared before and after surgery. Surgical success was defined as co-existence of 1) 50% or greater reduction in preoperative AHI, and 2) postoperative AHI to <-20 events/h [30]. OSA cure was defined as a postoperative AHI of fewer than 5 events/h.

2.4. Secondary outcomes

The Epworth Sleepiness Scale (ESS) for evaluation of daytime sleepiness symptoms and the visual analog scale (VAS) for subjective evaluation of snoring before and after the surgery were used. The other secondary outcomes were the minimum oxygen saturation ($minO_2$), the mean oxygen saturation ($meanO_2$), oxygen desaturation index (ODI), and the percentage of sleep time with saturation below 90% ($SaO_2 < 90\%$). Complications, the postoperative period to beginning of normal feeding, and weight gain or loss before and after surgery were recorded. When required, the patients received intravenous tramadol by the way of patient-controlled analgesia (PCA) after surgery, using a PCA device.

2.5. Statistical analyses

Statistical analyses were performed by using SPSS for Win. Ver. 15.0 (SPSS Inc., Chicago, IL., USA). The variables were expressed as mean ± standard deviation (SD). Comparisons of preoperative and postoperative parameters in each surgery group were evaluated by using Wilcoxon test. Significance was defined as $p < 0.05$.

3. Results

The study population consisted of 1 female and 40 male patients with a mean age of 42.17 ± 9.50 years. The mean body mass index was 27.18 ± 2.69 kg/m^2, and the mean follow-up period was 6.8 ± 6.0 months. The types of surgical interventions are seen in Table 1. The mean AHI in the study group before and after surgery was 29.13 ± 15.87 events/h and 14.28 ± 16.14 events/h, respectively. The difference between pre- and post-operative AHI levels was statistically significant ($p < 0.001$) (Table 2). According to the classical definition of success criteria as aforementioned, the surgical success occurred in 23 of the 41 patients (56.1%), with cure of OSA in 17/41 patients (41.4%) (the percentage of surgical success includes the percentage of surgical cure).

Table 1
Types of velopharyngeal and hypopharyngeal surgical interventions.

Velopharyngeal surgeries	Hypopharyngeal surgeries
Anterior palatoplasty (n = 13)	Tongue base suspension (n = 24)
Cahali lateral pharyngoplasty (n = 11)[b]	Thyrohyoid suspension (n = 9)
Expansion sphincter pharyngoplasty (n = 10)[b]	Mucosal sparing partial glossectomy (n = 6)
Tonsillectomy (n = 7)[a]	Mandibulohyoid suspension (n = 2)
Uvulopalatal flap (n = 6)	Genioglossus advancement (n = 2)
Modified UPPP (n = 2)[b]	Epiglottoplasty (n = 1)
Z-palatoplasty (n = 2)[b]	
Transpalatal advancement pharyngoplasty (n = 2)	

[a] Only 1 patient underwent tonsillectomy alone as a velopharyngeal part of multilevel surgery. Other 6 patients underwent tonsillectomy combined with uvulopalatal flap or anterior palatoplasty.
[b] Includes tonsillectomy as a part of surgical technique.

Table 2
Clinical and respiratory parameters of the patients before and after multilevel surgery.

Type of surgical intervention	VS + SR (n = 34)			VS + TRA (n = 7)			All patients (n = 41)		
	Preop (mean ± SD)	Postop (mean ± SD)	p	Preop (mean ± SD)	Postop (mean ± SD)	p	Preop (mean ± SD)	Postop (mean ± SD)	p
BMI	27.03 ± 2.30	26.46 ± 2.10	<**0.001**	27.84 ± 4.26	27.40 ± 3.77	0.138	27.18 ± 2.69	26.62 ± 2.43	<**0.001**
AHI	28.50 ± 15.66	14.49 ± 16.19	<**0.001**	32.14 ± 17.76	13.27 ± 17.10	**0.028**	29.13 ± 15.87	14.28 ± 16.14	<**0.001**
ESS (0–24)	11.70 ± 4.55	6.58 ± 3.87	<**0.001**	15.57 ± 3.77	5.71 ± 2.05	**0.018**	12.36 ± 4.63	6.44 ± 3.62	<**0.001**
VAS (0−10)	9.29 ± 1.05	3.41 ± 2.47	<**0.001**	9.00 ± 2.23	2.00 ± 1.63	**0.026**	9.24 ± 1.30	3.17 ± 2.39	<**0.001**
$meanO_2$	91.08 ± 2.14	93.07 ± 1.89	**0.001**	92.08 ± 2.41	93.33 ± 1.75	0.068	91.29 ± 2.19	93.13 ± 1.83	<**0.001**
$minO_2$	74.44 ± 11.69	85.68 ± 5.24	<**0.001**	84.00 ± 5.94	90.57 ± 3.40	**0.018**	76.53 ± 11.34	86.75 ± 5.27	<**0.001**
$SaO_2 < 90$ (%)	13.83 ± 9.27	8.54 ± 14.58	**0.018**	15.15 ± 8.41	7.85 ± 7.84	0.180	13.94 ± 9.05	8.48 ± 14.05	**0.010**
ODI	19.94 ± 11.79	8.46 ± 14.63	<**0.001**	15.05 ± 10.53	5.60 ± 5.37	0.180	19.55 ± 11.57	8.23 ± 14.07	<**0.001**

VS = velopharyngeal surgery, SR = suture/repositioning procedures as hypopharyngeal surgery, TRA = tissue resection/ablative procedures as hypopharyngeal surgery, SD = standard deviation, BMI = body mass index, AHI = apnea hypopnea index, ESS = Epworth score, VAS = visual analog scale, $minO_2$ = lowest oxygen saturation, $meanO_2$ = mean oxygen saturation, ODI = oxygen desaturation index, $SaO_2 < 90$ = percentage of sleep time with SaO_2 below 90%, significance was defined as $p < 0.05$.

The number of patients undergoing DISE two weeks before the multilevel surgery was 13 (31.7%).

After surgery, the mean ESS scores significantly improved from 12.36 ± 4.63 to 6.44 ± 3.62, and the mean VAS snoring scores significantly improved from 9.24 ± 1.30 to 3.17 ± 2.39 ($p < 0.001$). Also, multilevel surgical treatment provided statistically significant improvements in the mean values of respiratory parameters of the $minO_2$ ($p < 0.001$), the $meanO_2$ ($p < 0.001$), the $SaO_2 < 90$ ($p = 0.010$), and the ODI levels ($p < 0.001$) (Table 2).

There were 3 patients having postoperative major complications, including secondary bleeding requiring surgical intervention under general anesthesia (2 patients), and severe tongue base edema in 1 patient undergoing a tongue base suspension which regressed by steroid administration and didn't need tracheotomy. There were 61 minor complications, including pain (26 patients), difficulty in swallowing (21 patients), velopharyngeal insufficiency (8 patients), minor bleeding controlled by office-based approach (2 patients), globus sensation (2 patients), regurgitation (1 patient), and occlusion disorder (1 patient) (Table 3). Non-specific complaints such as throat discomfort, dry throat, frequent throat clearing, and subjective taste changes were observed in some patients following operation, but only a few days. The majority of complications resolved during follow-up period without sequelae. None of the patients indicated any persistent complication at the time of postoperative PSG except 2 patients who have suffered from globus sensation. We did not experience any type of airway obstruction postoperatively. No tracheotomy was needed in the study population.

To control and reduce postoperative pain, 26 of 41 patients required opioid support (tramadol) with the PCA device, but no more than postoperative 2 days. The mean period after surgery to beginning of normal feeding was 1.81 ± 1.01 days (min = 1, max = 5 days). After surgery, some patients have lost weight during follow-up period. The mean preoperative and postoperative BMI were 27.18 ± 2.69 and 26.62 ± 2.43, respectively, and the difference was statistically significant ($p < 0.001$).

When we divided patients into two subgroups according to type of hypopharyngeal surgery as a suture/repositioning group (SR) (n = 34) and a tissue resection/ablative group (TRA) (n = 7); we found that, the percentages of pain, the number of patients with major bleeding requiring operative intervention, and the percentage of PCA use were higher in the TRA group. In addition, the mean postoperative period to beginning of normal feeding was a little longer in the TRA group than the SR group. However, surgical cure and surgical success rates were better in the TRA group (Table 3).

4. Discussion

In this study, we have shared our clinical experience regarding different combinations of velopharyngeal and hypopharyngeal OSA surgeries as single-stage multilevel surgical interventions. According to the classical definition of success criteria, the surgical success was 56% and surgical cure was 41%. The surgical success rate of 56% seems to be relatively lower compared with CPAP, but it is known that compliance and adherence problems are common with PAP therapies. Providing a surgical cure of 41% with single-stage surgical procedures is a remarkable finding to offer these surgeries to OSA patients as an alternative to PAP treatment, if we consider that approximately 20%–80% of patients quit using PAP devices for any reason [5,6]. Nevertheless, multilevel surgery for OSA should be limited to patients who have already undergone an unsuccessful attempt of CPAP or completely stopped CPAP therapy [31].

Table 3
Postoperative evaluation of the patients.

Type of surgical intervention	VS + SR (n = 34)	VS + TRA (n = 7)	All patients (n = 41)
The mean postoperative evaluation time	6.70 ± 5.41 months	7.42 ± 8.86 months	6.82 ± 6.00 months
Complications	Pain (n = 20) Difficulty in swallowing (n = 18) Velopharyngeal insufficiency (n = 8) Minor bleeding (n = 2) Globus sensation (n = 2) Regurgitation (n = 1) Occlusion disorder (n = 1) Severe edema (n = 1)	Pain (n = 6) Difficulty in swallowing (n = 3) Major bleeding (n = 2)[a]	Pain (n = 26) Difficulty in swallowing (n = 21) Velopharyngeal insufficiency (n = 8) Major bleeding (n = 2)[a] Minor bleeding (n = 2) Globus sensation (n = 2) Regurgitation (n = 1) Severe edema (n = 1) Occlusion disorder (n = 1)
Postoperative use of PCA	n = 20 (58.8%)	n = 6 (85.7%)	Used (n = 26; 63%) Not used (n = 15; 37%)
The mean postoperative period to beginning of normal feeding	1.80 ± 1.04 days	1.88 ± 0.89 days	1.81 ± 1.01 (min = 1, max = 5) days
Surgical cure	n = 13 (38.2%)	n = 4 (57.1%)	17/41 (41.4%)
Surgical success	n = 17 (50%)	n = 6 (85.7%)	23/41 (56.1%)

VS = velopharyngeal surgery, SR = suture/repositioning procedures as hypopharyngeal surgery, TRA = tissue resection/ablative procedures as hypopharyngeal surgery, PCA = patient-controlled analgesia.
[a] Complications requiring operative intervention.

As a general rule of OSA surgeries, all sites of airway obstruction should be identified before performing any surgery to modify obstructed pharyngeal airway segments and obtain optimal surgical outcomes [32]. Presence of multilevel obstruction may impair the results of any velopharyngeal surgery which is performed alone. Moreover, OSA patients with multilevel obstruction cannot benefit from only hypopharyngeal surgery when it is performed as a single surgery. If OSA surgery is performed as multilevel surgery, the postoperative polysomnographic results will reflect the combined effect of all performed surgeries. Relatively poor improvement or no improvement from hypopharyngeal surgery may impair the total result, and vice versa, failure of velopharyngeal surgery will impair the combined success rate. Because the patients in this study underwent multilevel surgery targeting two levels, it is not possible to demonstrate which level of combined surgery was more beneficial. Thus, we cannot predict which level of obstruction or how much severity of obstruction causes the AHI severity the most. Therefore, correction of multilevel obstruction by multilevel surgery affects PSG results synergistically. In addition, continuous nasal obstruction may lead to persistent complaints and impair the outcomes of multilevel surgery. According to our clinical practice, firstly nasal obstruction should be resolved before performing any OSA surgery. Therefore, all patients investigated in this study were those who did not have any nasal problems before multilevel surgery.

The management of hypopharyneal level is more difficult than that of velopharyngeal level. The purpose of hypopharyngeal surgery is to increase the size of the retrolingual airway by providing tissue volume reduction or using suspension techniques. We have used TBS in 24 patients. The major concern regarding this surgery is the relapse that we did not experience in any of 24 patients during follow-up period. To present objective results of TBS and to talk about the relapse, long-term check-up is needed. The hypopharyneal procedures are technically more difficult, more invasive, and most of them are time consuming [33]. So, many surgeons prefer tissue resection from tongue base with different devices. A kind of minimally invasive technique for tongue base, MSPG, aims to improve retrolingual airway by providing submucosal tissue resection from tongue base by using the coblation technique. This technique minimizes the risk of trauma and edema, therefore reduces morbidity. We didn't experience any airway collapse or life-threatening bleeding with this method.

Single level or multilevel OSA surgery should be discussed in terms of complication rates because this topic is controversial. Kezirian and colleagues found that concomitant UPPP and retrolingual procedures resulted in a higher complication rate compared with concomitant UPPP and nasal surgery [34]. On the other hand, Baker et al. found no significant increase in postoperative complications when UPPP combined with multilevel procedures was compared with UPPP alone in the treatment of OSA [35]. The vast majority of complications were minor in our study population. Only 3 patients experienced safety problems; 2 of them were bleeding requiring operative intervention and the other one was severe tongue edema regressed by close follow-up and steroid treatment. None of the patients in the study group needed tracheotomy neither intraoperative nor postoperative period. When nonsteroidal anti-inflammatory drugs were insufficient to reduce postoperative pain, we used tramadol with PCA device. Use of opioid did not require longer than two days and we returned to classical pain-killers after PCA. Since the mean period after surgery to normal diet was 1.8 days, the patients did not experience severe difficulty while feeding. Total of 21 patients indicated difficulty in swallowing and these complaints diminished during follow-ups. At the time of postoperative PSG, only 2 patients stated they had globus sensation as a persistent complaint. Even though the success rate of multilevel surgery was 56%, improvements in the ESS and VAS scores were statistically significant. Besides AHI levels, respiratory parameters were also significantly better after surgery at the mean postoperative 6.8 months. All these results of this study show that major concerns such as airway safety and postoperative morbidity with multilevel OSA surgeries are not as severe as they seem.

Another important issue regarding postoperative morbidity and complications is the type of hypopharyngeal surgery when it is combined with velopharyngeal surgery. When we examined the patients into two subgroups as SR and TRA groups; we detected that the percentages of pain, the number of patients with major bleeding requiring operative intervention, and the percentage of PCA use were higher in the TRA group. Moreover, as it was expected, the mean postoperative period to beginning of normal feeding was longer in the TRA group than the SR group. Previous studies have also reported that the ablative/tissue resection procedures such as midline glossectomy, lingual tonsillectomy and transoral robotic surgery (TORS) had significantly higher levels of complications and would not necessarily thus yield as safe a profile when combined with velopharyngeal procedures [10,36]. Due to relatively lower number of patients undergoing tissue resection procedures, the data from present study does not provide sufficient information with regard to a potential superiority of SR procedures over TRA techniques. To make a reliable comparison between these techniques and to avoid possible bias arising from poor power analysis, larger case series are needed for both groups.

In OSA surgeries, duration of surgery and cost should also be taken into consideration. In the last decade, TORS has also become popular by providing improvement in visibility and dexterity for tongue base approaches, but the operation time and cost are not ignorable and limit its use. Moreover, “no tissue feedback of hands” with TORS is an important handicap for some surgeons. One of the recent meta-analysis showed that the overall success rate of TORS as part of a multilevel surgery was 48.2% [10]. In addition, the cost for multilevel surgeries without using TORS is less than that of performed with TORS methods. In both techniques, time gain with single-stage procedures is superior to multi-stage procedures. Instead of undergoing general anesthesia twice for multi-stage multilevel surgery, patients may undergo general anesthesia only one time with single-stage multilevel surgery. Another important point related to anesthesia is which type of intubation is better. We usually prefer orotracheal intubation, but, if oral intubation tube is thought to restrict the view of the operation field, particularly in small mouths, nasal intubation can be requested from anesthesiologist to increase surgical comfort. We also insist on nasotracheal intubation for the intraoral surgical interventions addressing tongue base.

The obesity plays an important role in the outcomes of sleep apnea surgeries. There is strong evidence about this issue in the literature that the success of surgical treatment for OSA is lower in obese patients compared with non-obese patients and relapse of OSA is commonly seen in obese patients in the long-term [37,38]. In this study population, the mean BMI was 27.18 ± 2.69 kg/m^2 which reveals subjects were normal or slightly overweight. None of the subjects were obese. Moreover, it has been reported that obese patients with OSA have enlarged tongue volumes and increased fat within the tongue [39]. Since tongue base and lingual tonsil region is not rich in soft tissue in non-obese patients, suture repositioning techniques rather than tissue resection procedures are more appropriate for these patients. Selection of type of hypopharyngeal surgery in our study was compatible with this BMI that most of the patients underwent suture repositioning procedures.

The limitations of the study are the followings: [1] lack of a control group due to retrospective nature of the study, [2] relatively short follow-up period, [3] small number of subjects, and [4] heterogeneity of patients who underwent several combinations of procedures. We were ought to exclude many patients due to the absence of postoperative PSG. We think that patients who get rid of OSA symptoms after surgery are more reluctant to undergo postoperative PSG. On the contrary, patients with persistent symptoms are more likely to visit hospital again to undergo postoperative PSG. In addition, DISE was performed in only small group of patients in this study ($n = 13/n = 41$). In the examination of obstructive sites of upper airway, DISE is a necessary tool and capable of determining the need for multilevel surgery. However, one of the recent studies has showed that both Müller's maneuver and DISE methods revealed the same obstruction levels in OSA patients, and

therefore, the authors suggest that Müller's maneuver is reliable to be used to indicate possible obstruction sites when DISE cannot be used [40].

5. Conclusion

When indicated, multilevel procedures can be safely performed for treatment of OSA at a single-stage. Complications are not much more than those seen with single-level surgical treatments. Further prospective studies with large homogeneous case series showing long-term outcomes will provide more benefit regarding the effect of single-stage, multilevel surgeries for OSA.

Conflict of interest

None of the authors has any conflict of interest, financial or otherwise.

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