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Obstructive Sleep Apnea Surgical Options: A Phenotypical Approach

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Abstract

As a consequence of being a multifactorial disease, multiple mechanisms are involved in OSA pathophysiology, including not only anatomical causes but also causes related to the muscular response during sleep and its effect on pharyngeal wall resistance, both predisposing the upper airway to collapse.

The scientific evidence for OSA surgical treatment suggests that it must be indicated in well-selected cases, mostly in patients presenting anatomical causes, either by tissue hypertrophy or by craniofacial deformities.

Electrical stimulation of the hypoglossal nerve presents promising results, reinforcing the role of the muscular response in OSA pathophysiology.

The greatest challenge in choosing the best surgical treatment option is to define the predominant factor in each candidate, concept called phenotype, which explains the existence of numerous surgical options, presented in a comprehensive way in this paper.

Keywords: Drug-induced sleep endoscopy, Obstructive sleep apnea, Sleep apnea surgical treatment, Sleep-disordered breathing, Upper airway stimulation

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Introduction

Obstructive sleep apnea syndrome (OSAS) is the most frequent respiratory sleep disorder, with a prevalence up to 35% in the adult male population.[1] It is a progressive disease and represents a burden to public health, increasing the risk of traffic and occupational accidents and the occurrence of metabolic syndrome, neurocognitive deficit and cardiovascular diseases, such as hypertension, acute myocardial infarction and stroke.[2,3]

Polysomnography (PSG) is the gold standard test for diagnosing OSAS, allowing to score its severity according to the number of respiratory events per hour of sleep (AHI), including information about the disturbance in blood oxygen saturation during these events.[4]

The continuous positive airway pressure (CPAP) is considered the first treatment option in moderate and severe cases. However, long term adherence rates are variable,[5,6] which compromises the outcome of this therapy and justifies the search for surgical treatment options.[7–9]

Various mechanisms are involved in OSA pathophysiology,[10,11] including not only factors related with the upper airway anatomy (craniofacial deformities or tissue hypertrophy) but also factor affecting the pharyngeal wall resistance and muscular response during sleep, both predisposing the upper airway to collapse.[12]

As a consequence of being a multifactorial disease, which explain the existence of numerous surgical options, the greatest challenge in choosing the best surgical procedure is to define the predominant factor in each individual, concept called phenotype, which will be presented in a comprehensive way in this paper.

Nasal Surgery

Nasal pathologies interfere directly with respiratory resistance, possible contributing to OSA pathophysiology.[13,14] The main attempt to explain the correlation between nasal obstruction and respiratory sleep disorders is based on Starling's resistor model, in which the upper airway would correspond to a flexible tube and the obstruction at its entrance (nose) would cause an increase of negative pressure inside this tube (pharynx), contributing to its collapse.

Oral breathing is another important point to consider, since increases up to 2.5 times the airway resistance and favor pharyngeal collapse,[15] both by reducing retropalatal and retroglossal area, consequence of mandible rotation and posterior displacement of the tongue, and by compromising the contraction of the suprahyoide expansive muscles.[16,17]

The chief complaining of nasal obstruction must be clinically evaluated through anterior rhinoscopy and nasal endoscopy. Symptoms related to allergic rhinitis may lead to inferior turbinate hypertrophy and ought to be initially treated with topical steroids. Surgery is generally considered when turbinate hypertrophy did not respond to clinical treatment, in the presence of obstructive nasal septum deviation or nasal valve insufficiency.

Nasal blockage is a frequent complaint among OSA patients, its surgical treatment improves symptoms such as daytime sleepiness and fatigue but does not promote enough reduction in disease severity.[18] Evidence suggests that the role of nasal surgery is to facilitate mandible repositioning devices (MAD) adaptation[19,20] and to enable the use of CPAP nasal mask, which is more effective than the oronasal models in controlling the obstructive events, thus increasing adherence.[6,20]

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Soft Tissue Surgeries

Uvulopalatopharyngoplasty (UPPP) is the most performed procedure in OSA surgical treatment. However, systematic reviews have demonstrated that only 45% of the cases meet the success criteria adopted in the literature (reduction of AHI by at least 50% and final value <20 events/hour), suggesting that it should be indicated only for well selected cases.[21,22]

In order to improve patient selection for UPPP, Friedman developed a staging system based on the anatomical evaluation of the oral cavity, describing phenotypes correlating the palatine tonsil size, the relation between the soft palate and tongue position and the body mass index.[23–25]

Based on a retrospective review of cases submitted to UPPP, 23% of patients had tonsils grade 3 or 4 and Friedman tongue position 1 or 2 and were included in stage 1. The surgical success rate up was to 80% in this group, where tonsillectomy alone could also be beneficial.[26] In the other groups, the success rate was below 40%.

Motivated by the limited success rate of UPPP, other surgical techniques targeting the lateral pharyngeal wall were described in the past decade, being the lateral pharyngoplasty and the expansion pharyngoplasty the most widespread,[27,28] achieving a mean success rate of 65% in patients staged as 2 and 3, according to Friedman scoring system.

The purpose of these techniques is to avoid the pharyngeal collapse by repositioning the lateral pharyngeal wall muscles in order to increase the area and the wall resistance with the additional benefit of preserving the soft palate, thus minimizing the risk of turning CPAP unfeasible in the future.

Nevertheless, a relevant percentage of patients still do not respond satisfactorily[29] and the hypopharyngeal obstruction has been pointed out as a possible explanation for the unresponsive cases.[30,31]

On the other hand, procedures for tongue base reduction have demonstrated favorable results,[32] where one of surgical techniques that presented best outcomes was described by Vicini et al. using the transoral robotic surgery.[33]

It is performed using the Da Vinci® surgical system, which consists in a surgeon console, a patient cart and a control tower. The patient cart offers up to 4 robotic arms, but only three are used in this surgery: one connected to a 3D high-definition camera that provides an image with up to 10x zoom throughout 8 mm diameter endoscope (0º or 30º) and other two attached to 270º movement instruments (Endo Wrist®), a Maryland bipolar grasping and a Monopolar spatula, positioned on each side of the camera. The console enables the surgeon to control all the arms simultaneously.

The objective of this procedure is to enlarge the size of the retroglossal area and to improve the epiglottis positioning, reducing the possibility of hypopharyngeal obstruction. The resection of the hypertrophied tissue extends from the foramen cecum to the vallecula, including the mucosa covering the epiglottis and eventually a small upper portion of the cartilage if necessary.

The goal is to remove completely the hypertrophied lingual tonsil, but additional muscular resection of the tongue may be necessary to improve the exposure of the glottic area. In order to prevent vascular damage and bleeding, the resection occurs mainly in the midline area, taking special care when dissecting more laterally, where the risk of arterial bleeding is higher.

This procedure is also feasible to be achieved using Coblation technology,[32] but the final outcomes may be related with the amount of tissue resected.[34] The association of pharyngeal procedures enable to treat simultaneously also the lateral pharyngeal wall collapse and increases favorably the success rates.[35]

However, although several studies have demonstrated that surgical procedures addressing more than one level of the upper airway (multilevel surgeries) can provide better results, systematic reviews show inconsistent data,[36] suggesting that the success rate may still be dependent on the criteria adopted for patient selection. Therefore, there is room for improvement in patient selection for soft tissue surgery, even when addressing multilevel obstructive sites.

Drug-induced Sleep Endoscopy

A possible explanation for the great variability in OSA surgical treatment outcomes may be related to the criteria adopted for patient selection, generally using information obtained under awake condition, which may underestimate the role of muscular response in the pathophysiology of the disease.

Drug-induced sleep endoscopy (DISE), if performed in a standardized infusion protocol[37,38] is a complementary test able to produce a muscular relaxation similar to that occurring during sleep, allowing a dynamic and three-dimensional evaluation of the structures involved in the upper airway collapse.[39]

The comparison of obstructive sites in the upper airway, obtained in the same patient under awake condition and during DISE, demonstrates a high percentage of divergence, suggesting that the awake evaluation may underestimate hypopharyngeal and epiglottis obstructions, consequently overestimating the role of the soft palate and oropharynx as main factors in OSA.[40]

The actual impact of DISE in improving surgical outcome remains controversial in literature, but there is evidence that the test contributes to identify patterns of obstruction that correlated with UPPP failures,[41] favorable to functional expansion pharyngoplasty[42] and maxillomandibular advancement surgeries.[43]

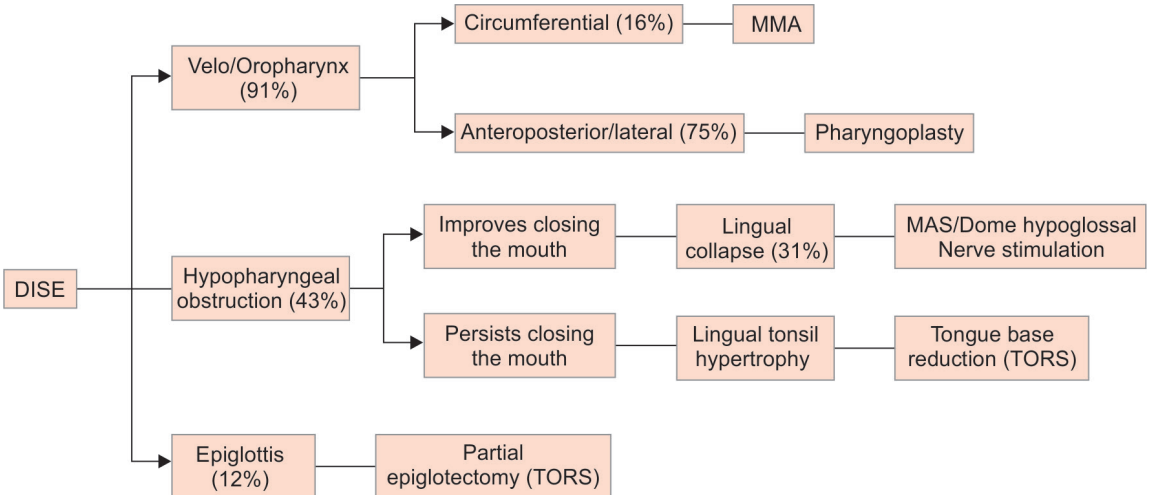
The velopharyngeal circumferential collapsed was also correlated with worse outcomes in upper airway stimulation treatment, determining by the FDA® the exclusion to this procedure candidates presenting this type of collapse during DISE.[44]

Regarding tongue base and hypopharyngeal surgery, the evidence suggests that DISE did not improve surgical outcome.[45] However, we advocate that often there is a misinterpretation of tongue base and hypopharyngeal collapse detected by DISE, taking into account only the obstructive site to propose the surgical procedure, ignoring the underlying mechanisms causing the collapse. Theoretically, the lack of muscular support can lead the tongue to collapse independently if the tissue is hypertrophied or not.

In our experience, DISE can be interpreted in such a way as to detect the tongue base collapse due to the lack of muscular support, though helping to identify with better accuracy patients in which the obstruction in the tongue base and hypopharynx is caused by soft tissue hypertrophy.

The way we have been using to do it is to close gently the mouth during DISE, without any mandibular advancement or neck hyperextension, in order just to make the tongue assume its proper position under the hard palate, observing if there is improvement of the retroglossal obstruction. Patients with persistent obstruction after this maneuver are more likely to have soft tissue hypertrophy in the tongue base and better candidates to undergo surgery (Flowchart 1).

Flowchart 1: DISE flowchart
MMA, maxillomandibular advancement; MAS, mandibular advancement splint; DOME, distraction osteogenic maxillar expansion; TORS, transoral robotic surgery



It is increasingly evident that the anatomy is not the only determinant factor in OSA physiopathology, the neuromuscular control during sleep seems to have a paramount role in OSA physiopathology.[46] Thus, the use of DISE to indirectly access the muscular response, contraindicating the surgery when the tongue base and hypopharyngeal obstruction occurs due to the lack of muscular support, can promote a positive impact in the surgical outcomes.[47]

The use of anesthetic drugs that alter the sleep architecture (important reduction or abolition of REM sleep) and might promote excessive muscular relaxation is one limitation of DISE, which is more evident in the detection of tongue base and hypopharyngeal obstruction, where the over sedation have direct impact in mechanism of collapse and may have negative impact in patient selection, if wrongly interpreted.

Upper Airway Stimulation

The impaired genioglossus activity is described in OSA physiopathology, leading to a tongue base obstruction due to lack of muscular support that may have a paramount role in pharyngeal obstruction, which can not be surgically treated.[48] The hypoglossal nerve (XII) is responsible for the activation of the genioglossus muscle, which is the main responsible for stabilizing the upper airway during sleep. The genioglossus muscle is inserted horizontally into the hyoid bone and its activation alters the balance of forces that determines the position of this structure, avoiding collapse by stabilization and dilation of the pharyngeal muscles.[49]

The insertion of an electrode to stimulate the hypoglossal nerve has proven to be an efficient treatment for OSA,[50] theoretically addressing the upper airway collapse caused by the impairment of muscular response during sleep, phenotype that may explain the limitation of the surgical treatment.

A prospective multicenter study[51] have showed 68% reduction in AHI during long-term follow-up of implanted patients, despite the difference in the mechanisms of electrical stimulation and activation of the hypoglossal nerve.[52]

In general terms, the device is a small generator consisting in a battery and a stimulation system (hardware and software), implanted in the upper side of the right chest, connected subcutaneously with electrodes positioned around the hypoglossal nerve in the submandibular region on the same side. The stimulus is turned on during the night and can be continuous, alternating the activated electrodes, or intermittent and synchronized with the inspiratory effort by a respiratory sensor, depending on the UARS model.

The procedure was approved for adults (>22 years of age) nonadherent to CPAP, with a BMI under 35 kg/m^2, apnea index greater than 20 events / hour and AHI less than 65 events / hour. The presence of circumferential pattern of collapse in the velopharynx in drug-induced sleep endoscopy (DISE) is one of the main exclusion criteria.[39,53]

Bone Architecture (Orthognathic) Surgeries

Several studies have demonstrated a relationship between facial phenotype and obstructive sleep apnea. Individuals with mandible and maxillary retrusion, transverse maxillary atresia, low position of the hyoid bone, and increased pharyngeal length, are more likely to present OSA.[54]

Regarding the treatment of craniofacial deformities and its impact on OSA, mandibular and genioglossal advancement alone does not have proven to be beneficial.[55–58] The surgically assisted expansion of the maxilla is a less invasive procedure and presents promising results in well selected patients.[59]

The maxillomandibular advancement surgery has a success rate close to 90% in cases where it is possible to achieve at least 10 mm of maxillary advancement, associated with the anticlockwise rotation of the mandible.[60] It is important to mention that the cure rate (AHI ≤5 events / hour) of this procedure is around 40% and the literature data refers to patients with a BMI lower than 35 kg/m^2.

These data reinforce the hypothesis that OSA patients may have other nonanatomical factor contributing to its physiopathology, such as the impairment of muscular response during sleep.[10,11,61–63] As the neuromuscular response is not likely to be successfully treated with bone surgery, the best surgical outcomes will be related with the objective detection of patients with maxillomandibular retrusion during preoperative evaluation.

Bariatric Surgery

The relationship between low sleep quality and weight gain has been well established by populational studies,[64,65] whereas a BMI above 29 increases the likelihood of OSA up to 10 times. Therefore, weight loss is expected to reduce the apnea severity.

Although clinical weight loss treatment promotes favorable results, a relapse in weight control with recurrence of OSA severity is observed in 45% of the cases within 2 years.[66–68] Bariatric surgery increases the chances of faster and longer lasting results and may be considered in morbid obesity (BMI >40), but it is an invasive procedure with higher morbimortality and must be discussed with caution.[69]

The reduction of 1 unit in the BMI corresponds to a reduction of 2.3 units in the AHI and regardless of its efficiency in loosing weight, only 5% of patients achieve cure (AHI <5) and the majority persists with moderate OSAS. These data also reinforce the multifactorial aspect of this disease, also suggesting that weight gain may be a complementary factor to increase the severity, but not an exclusive factor behind OSA physiopathology.

Final Thoughts

The scientific evidence for OSA surgical treatment suggests that all available procedures must be indicated in well selected cases, mostly in patients presenting anatomical causes, either by tissue hypertrophy (palatine and lingual tonsils) or by craniofacial deformities (maxilla transverse deficiency or maxillomandibular retrusion).

Electrical stimulation of the hypoglossal nerve presents promising results, which reinforces the role of muscle tone control mechanisms in the pathophysiology of OSAS.

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