Review Article

Reconstructive procedures for disturbed functions within the upper airway: pharyngeal breathing/snoring

Thomas Verse[1*]

[1]Department of Otorhinolaryngology, Head and Neck Surgery, University of Saarland, Homburg, Germany

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Abstract

Breathing disorders which have their origin within the pharynx mainly occur during sleep. These so-called obstructive sleep-related breathing disorders include three different disturbances which have to be distinguished properly: simple snoring, upper airway resistance syndrome (UARS) and obstructive sleep apnea (OSA). Each disturbance requires a different treatment.

Simple snoring does not affect the physical health of the snorer himself, but often leads to social problems due to the annoying character of the breathing sounds. Appropriate treatment modalities are oral devices and transcutaneous or ttransmucosal electrical stimulation of the muscles of the floor of the mouth via surface electrodes. As reconstructive surgical procedures adenotomies, tonsillectomies, tonsillotomies, or adenotonsillectomies are successfully used in children. Moreover, in adults radiofrequency treatments of the tonsils, the soft palate and of the base of tongue, as well as uvulopalatopharyngoplasty (UPPP), laser-assisted uvulopalatoplasty (LAUP) and palatal implants are adequate treatments for simple snoring.

Adequate therapies for UARS and mild OSA (less than 20 breathing events per hour of sleep) are oral appliances. Nasal continuos positive airway pressure (NCPAP) ventilation is a very successful treatment modality, but shows low compliance in these patients, as daytime symptoms like excessive sleepiness or or impaired cognitive functions are often unincisive in patients with mild OSA. Reconstructive procedures like UPPP, radiofrequency surgery of the tonsils or the base of tongue, hyoid suspension, mandibular osteotomy with genioglossus advancement (MO) are successful treatment options either as isolated procedures or in combination within so-called multi-level surgery concepts.

Goldstandard for the treatment of moderate to severe OSA is the nCPAP ventilation. All patients should at least try this treatment modality. Only in the rare cases of nCPAP failure (2%) and in the relatively frequent cases of nCPAP incompliance (30%) reconstructive surgical procedures become

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*Corresponding Author:
Priv.-Doz. Dr. med. Thomas Verse, Department of Otorhinolaryngology, Head and Neck Surgery, University of Saarland, Kirrberger Str.; D-66421 Homburg, Germany, Tel: #49-6841-16-22984, Fax: #49-6841-16-22997, eMail: thomas.verse@uniklinik-saarland.de

necessary as second choice treatments. These are adenectomies, tonsillectomies, tonsillotomies in children and hyoid suspension, MO, multi-level surgery concepts, or maxillomandibular advancement osteotomies in adults.

1. Introduction

Impairment of pharyngeal breathing mainly occurs during sleep. In the awake breathing may be compromised by tumors, infections, and allergic reaction like angioneurotic edema. The treatments of these disturbances are based on the specific disease. There are no specific reconstructive procedures. For this reason the present review deals with sleep related breathing disorders which have their origin within the pharynx. Various reconstructive procedures in this anatomical area have been introduced into modern sleep medicine within the last 20 years. These procedures will be discussed with focus to their efficacy in the treatment of sleep related breathing disorders.

2. Sleep related breathing disorders

The international classification of sleep disorders includes 80 different diagnoses of possible causes for non-restful sleep. A subgroup with a comparatively high incidence rate is formed by the so-called sleep-related disordered disorders (SRBD). These are further divided into disorders with and without obstruction in the upper airway. SRBD without obstruction include primary alveolar hypoventilation (Ondine`s curse syndrom), secondary alveolar hypoventilation, and central sleep apnea. These clinical syndromes have neurological causes outside the pharynx.

SRBD with obstruction include primary snoring, upper airway resistance syndrome (UARS) and obstructive sleep apnea (OSA). Currently, these syndromes are regarded as different grades of severity of the same pathophysiological disorder [1]. Snoring is caused by vibrations of soft tissue in constricted segments of the upper airway. By definition, primary snoring is not accompanied by breathing impairment, and entails neither a disruption of sleep nor an increased daytime sleepiness. Primary snoring may lead to a social problem as a result of the nocturnal breathing sounds, but it is not essentially a disorder of the patient's physical health.

Yet in the case of OSA, an imbalance exists between forces dilating and occluding the pharynx during sleep. The muscle tone supporting the pharyngeal lumen is too low, and the inspiratory suction force as well as the pressure of the surrounding tissue, both narrow the pharynx, are to high [2], [3]. This disorder occurs only during sleep due to a physiological loss of muscle tone of the pharyngeal muscles in this state. The effects are complete cessation of breathing (apneas) or reduced breathing phases (hypopneas). Both events trigger, if sustained long enough, an emergency situation for the body. The body reacts with a central arousal which disturbs the physiological sleep by a release of catecholamines. The latter lead via an increase of the tone of the sympathetic system to a strain upon the cardiovascular system.

In the case of UARS, the muscle tone is still sufficient to keep a partial lumen. Due to that the respiratory resistance is increased to an extent needing elevated respiratory efforts. After a certain amount of time this breathing impairment is interrupted by the same central nervous activation than seen when apneas are terminated. The result is an increased occurrence of respiratory arousals without detectable apneas [4].

In contrast to primary snoring, OSA and UARS have an adverse effect on the daytime life quality. Cardinal symptoms of OSA are intermittent snoring (94%), daytime sleepiness (78%) and diminished intellectual performance (58%). Further symptoms are personality changes (48%), impotence in men (48%), morning headaches (36%), and enuresis nocturna (30%) [5].

Obstructive sleep apnea (OSA) is a widespread disorder affecting up to 10.9% of the male and up to 6.3% of the female population [6], [7]. OSA is associated with serious adverse consequences for afflicted individuals, such as myocardial infarction [8], stroke [9], hypertension [10], and traffic accidents [11].

In other words, primary snoring is merely an irritating annoyance, whereas OSA and UARS represent diseases with a significant morbidity and mortality. This implies that distinct therapy goals are warranted. Therefore, it is considered as vital that a precise diagnosis is established before the initiation of any therapy. The necessary diagnostic work-up includes an anamnesis using standardized questionnaires, a physiological and otolaryngological assessment, and a sleep lab evaluation. For details see the relevant literature [12], [13].

The severity of SRBD is crucial in deciding which therapy is most suitable for which patient. The simple snorer is not ill. Therefore, the goal of treatment in the case of primary snoring lies in the reduction of both the duration and the intensity of snoring to a socially acceptable level. In principle, it needs to be kept in mind, 1. that a treatment should not harm the patient, 2. that a treatment should only be carried out if the patient has explicitly articulated such a wish, and 3. that after any treament nasal ventilation therapy should remain possible [14]. This last aspect is of importance due to the fact that the incidence of OSA increases with age and body weight [15]. Especially after aggressive soft palate surgery many cases have been described in which nasal ventilation therapy was no longer possible due to the development of a nasopharyngeal insufficiency or stenosis [16]. These cases have in many places seriously impaired the trust in soft palate surgery.

In the case of UARS and OSA, the goal of treatment consists in a complete elimination of all apneas, hypopneas, desaturations, arousals, snoring and other related symptoms in all body positions and all sleep stages. Of course, here it also has to be stressed that a treatment should in principle not harm the patient. But it must be pointed out that in the case of UARS and OSA a disease with corresponding symptoms is already manifest. Therefore, in order to achieve the therapy goal, one will be less reluctant to consider a more invasive therapy with heightened morbidity and complication rate, a decision which would not be defensible in the case of harmless primary snoring.

In general, the severity of OSA is classified according to the apnea hypopnea index (AHI; equals the number of apneas plus the number of hypopneas per hour of sleep). Unfortunately, especially in the case of the mild forms of SRBD, the AHI is not necessarily correlated to the clinical symptoms of the patients. Furthermore, the AHI is age-dependent. Concerning children, a widespread consensus exists that an AHI ≥ 2 is to be assessed as pathological. Newborns should not have any obstructive apneas. Concerning adults, no generally accepted consensus exists. He et al. [17] were able to demonstrate in an examination of 385 men with SRBD that the mortality risk rises significantly above an apnea index of 20. In our sleep lab we therefore use the following distinction:

• mild OSA: 10 ≤ AHI < 20

• moderate OSA: 20 ≤ AHI < 40

• severe OSA: 40 ≤ AHI.

Below an AHI of 10 it is necessary to make a differential diagnosis between harmless primary snoring and a potentially health-impairing UARS. It needs to be taken in account that the above values are applicable to 30 year olds. In the case of a 70 year old, an AHI of maximally 15 is still not necessarily in need of treatment if the patient does not have any daytime symptoms.

Apart from the AHI, the ailments of the patient play a role. That is, a patient with a UARS and an AHI of significantly below 10, but suffering from intense daytime sleepiness, may already be in need of treatment, whereas an older patient with an AHI of 15 may be fine without treatment. The concomitant diagnoses also need to be taken into account. Since SRBD constitute risk factors for myocardial infarction, arterial hypertension and strokes, patients with a corresponding anamnesis need to be sufficiently treated early on. One should also take special note of traffic accidents in the anamnesis, as these are frequently a result of sleepiness behind the wheel, which again suggests the existence of an SRBD.

Modern concepts regard primary snoring on the one hand and OSA on the other hand as different manifestations of the same pathophysiological disorder (Figure 1 (Fig. 1)) [1]. The author agrees with this conception and has made it the foundation for our therapeutic decisions. From Fiure. 1 (Fig. 1) two important therapy principles can be inferred for surgical interventions. On the one hand, a surgical therapy has to be performed more aggressively the more severe the SRBD is. For the treatment of primary snoring, non-surgical or minimally invasive techniques with a low complication rate should be preferred. In the case of moderate to severe OSA, surgery is only secondarily indicated after an unsuccessful nasal CPAP-therapy. For a primary surgical treatment, an AHI of approximately 30 is considered as threshold value [18].

The second therapy principle entails the notion that nowadays SRBD is more and more considered as a disorder of the entire upper airway. For many years, ENT surgeons, by only assuming two sites of obstruction, pursued a concept which from our perspective is too mechanistic. Fujita, for example, classified OSA patients into those with an obstruction solely behind the soft palate (type I), those with an obstruction solely behind the tongue (type 2), and those with an obstruction both behind soft palate and tongue (type III) [19]. Table 1 (Tab. 1) summarizes the established techniques of this topodiagnosis.

Yet up to now, this topodiagnosis has not been conductive in e.g. raising the success rate of soft palate surgery significantly above 50%. Therefore, this simpified classification into a retropalatal and a retrolingual site of obstruction is only applicable for primary snoring and, to a certain extent, in the case of UARS and mild OSA. Starting with moderate OSA, that is from an AHI of approximately 20 on, there is a need, in accordance with our experiences and assessments, for a surgical treatment of both of the two mentioned, potential sites of obstruction along the lines of so-called multi-level surgery (see 5.6.). Also in this case, the appropriate combination depends upon the severity and the anatomical disposition.

In the following, the surgical methods addressing the pharynx are discussed according to their anatomical position, beginning with the nasopharynx and ending with the base of tongue. Nasal surgery is addressed in the previous, laryngeal surgery in the following review of this Verhandlungsbericht.

For each case, the results concerning the efficacy of the particular technique for primary snoring and OSA will be presented separately based on the criteria of evidence based medicine (EBM) [20], [21]. In isolated cases the issue are discussed separately for children and adults.

3. Conservative reconstructive procedures

Conservative methods include weight reduction, optimizing of sleeping hygiene, conditioning in respect to the avoidance of certain sleep positions and medicinal treatments.

Obesity constitutes a major risk factor for SRBD [22]. Several studies have shown that a weight reduction significantly improves an OSA in the short run. But the long term success rate does not lie above 3 percent [23].

The maintenance of a certain level of sleeping hygiene (avoidance of alcohol and sedatives, reduction of nicotine and other noxious substances, observance of a regular sleep rhythm, etc.) is part of the standard recommendations in the treatment of SRBD. Obviously, no controlled long-term studies exist relating to these measures.

In the case of positional OSA, apneas and hypopneas occur predominantly or solely only in supine position. In these cases one should always consider the existence of a primarily retrolingual obstruction site. In supine position, the tongue, in accordance with gravity, falls backward due to the physiological muscle relaxation. As a result of the lower mass, this effect apparently plays a lesser role in the case of the soft palate. As yet, no long-term results exist concerning conditioning in regards to body position (prevention of supine position). Short-term therapy success of 75% has been documented in the case of mild and moderate positional OSA [24].

Hein and Magnussen [25] have gathered evaluations of 43 pharmaceuticals which were tested on patients with SRBD. None turned out to be effective in treating SRBD.

4. Apparative reconstructive procedures

Apparative treatment options include respiratory treatment with continuous positive airway pressure (CPAP) with its various modifications, oral appliances, and electrostimulation.

The CPAP ventilation therapy according to Sullivan [26], which is for the most part nasally applied, splints the upper airway pneumatically from the nares to the larynx. Concerning the implementation of CPAP therapy, and its diverse modifications, please refer to the specialized literature [27]. The method can reduce or eliminate symptoms such as snoring, daytime sleepiness, and cardiovascular risk factors. Two excellent studies which fulfilled the criteria of EBM (EBM I), demonstrated the efficacy of nasal CPAP [28], [29]. With a primary success rate of 98%, CPAP therapy is alongside tracheotomy the most successful therapy modality available. Unfortunately, the long-term acceptance rate of CPAP therapy lies below 70% [30]. The acceptance rate of CPAP therapy especially decreases the younger the patient is, and the less his subjective ailments improve with a CPAP therapy [31]. As a consequence, many patients with moderate and severe OSA in need of treatment have to be secondarily guided into another therapy. Often surgery is successful in these cases [32].

Among the oral devices mandibular advancement appliances have proven to be the most effective treatment while at the same time entailing the least amount of side effects. For mild to moderate OSA success rates of 50-70% have been reported [33], [34]. Unfortunately, individual success as well as compliance cannot be predicted with a sufficient degree of accuracy. Subjective compliance of oral devices is found to be 40-80% [35], [36]. Main side effects are hypersalivation, xerostomia, temporomandibular joint pain and dental discomfort which can be found in almost 80% of the patients [37].

Currently, electrostimulation as standard procedure is only available for the transcutaneous or transcutaneous-transmucous application. Initial data from small case-control studies display a short-term subjective success in the treatment of simple snoring but not for OSA [38], [39] . Long-term results are not yet existent.

5. Surgical reconstructive procedures

5.1. Nasopharynx

In childhood, adenoidal hypertrophy is a common feature predisposing SRBD. Pediatric OSA is equally common in both sexes [40]. Today, there is evidence that the relative adenoid size strongly correlates with the severity of OSA in children [41], [42]. A positive correlation between snoring and adenoid size was already described more than 20 years ago [43].

There are some report of enlarged adenoids may be associated with ventilatory impairment which is reversible after adenoidectomy [40], [44]. However, an isolated adenoidectomy does neither seem to be as effective as an isolated tonsillectomy nor as a combined adenotonsillectomy for OSA. Nevertheless, isolated adenoidectomy has been shown to improve mental performance in children [45].

Apart from enlarged adenoids, antral choanal polyps (ACP) may cause snoring or even OSA in children. Only a few cases have been described with snoring of children as a symptom of ACP [46], [47], and only three well-documented cases of pediatric OSA caused by ACP exist in the literature [48], [49], [50], [51].

In adults however, a complete obstruction of the nasopharynx rarely occurs. Donnelly et al. [52] recently found significantly reduced nasopharyngeal patency and significantly enlarged adenoids in 16 young sleep apneics as compared to 16 age-matched controls.

5.2. Tonsils

5.2.1. Tonsillectomy and tonsillotomy

It seems certain that one of the main reasons for obstructive sleep apnea (OSA) in children is obstructive tonsillar hypertrophy [53], [54]. It has been demonstrated previously that adenotonsillectomy during childhood cures OSA with high efficiency. However, it is not as clear to what extent tonsillar hypertrophy can also be considered as a cause for OSA in adults, and whether tonsillectomy is effective in these latter cases. For this reason the issue will be discussed separately for children and adults.

Furthermore, tonsillotomy [55] and different interstitial thermal ablation techniques [56] have recently been (re)introduced into the field of sleep surgery. These new developments give this issue new topicality. As radiofrequency surgery is a completely different operative technique it will be discussed separately.

A) Children

Efficiacy for simple snoring

Surprisingly there are only a few studies focussing on the efficacy of tonsillar surgery for simple snoring. Altogether there are data about 265 children [55], [57], [58], [59], [60]. The mean treatment success is given as 91% (88 to 100%). Especially to be mentioned is the work by Hultcranz and colleagues [55], who in a randomized study investigated the efficacy of tonsillotomy compared to tonsillectomy. Efficacy of both techniques was similar with signficantly lower postoperative morbidity rate in children who underwent tonsillotomy. In another controlled study Stradling et al. [61] examined 61 children before and 6 months after adenotonsillectomy, as well as 31 healthy, age-matched children at the beginning of the study and 6 months later. In the group of the children having received surgery, the oxygen saturation and the movement time during sleep, as well as various subjective parameters, were normalised to the level of the untreated, healthy children.

Furthermore several studies have demonstrated that children who suffer from snoring perform weaker in school than their non-snoring peers [62], [63], and that these deficits can be eliminated with an adenotonsillectomy [64].

Efficacy for OSA

The spontaneous resolution of OSA secondary to adenotonsillar hypertrophy within a one-year observation period has been reported at only 9% [58]. Therefore, adenotonsillectomy is the most common major surgical procedure performed on children [53], [54], [65]. Altogether 9 studies present data of 221 children [40], [57], [65], [66], [67], [68], [69], [70], [71], [72]. The mean success rate (AHI postop. < 5) is calculated as 85.8%. Therefore adenotonsillectomy should be regarded as effective in the treatment of OSA in children. Kudoh and Sanai found that adenotonsillectomy was remarkably effective even in children with morbid obesity [73].

In some children, obstructive symptoms recurred years later. Guilleminault [74] reported recurrent OSA during the pubertal growth spurt in adolescents who as children had undergone adenotonsillectomy for relief of adenotonsillar hyperplasia and OSA and who had been free of obstructive symptoms over several years. In a follow-up study performed after an average 7.5 years, Guilleminault found radiocephalometric evidence of anatomic anomalies particularly behind the tongue (PAS) and in the mandible as an explanation for recurrence of OSA [75]. These findings show that children treated successfully with adenotonsillectomy for OSA should continue to be monitored, particularly those in families with a history of bite abnormalities which reach their full manifestation during puberty.

b) Adults

Efficacy for simple snoring

No sufficient data exist in the literature documenting any positive effect of isolated tonsillectomy on simple snoring in adults.

Efficacy for OSA

Since substantial hypertrophy of the palatine tonsils is rare in adults, there is little data available. All in all, there are 28 complete sets of data of sleep apnea patients who exclusively underwent tonsillectomy. The average number of breathing events per hour of sleep sank from preoperative 45.2 to postoperative 13.1. This difference is statistically highly significant. In accordance with the success criteria of Sher [76] this amounts to a healing rate of 78.6% in this selected patient pool. From these data it can be inferred that a massive tonsillar hyperplasia is rarely seen in adults, but if it exists, tonsillectomy for the treatment of OSA is almost as successful as in childhood.

5.2.2. Radiofrequency surgery (RFQ)

Radiofrequency techniques use high-frequency current to either cut or coagulate tissue. If used as an interstitial treatment a submucousal needle electrode is inserted into the soft tissue. By applying radiofrequency energy, a thermic lesion is created followed by subsequent scarring. As a result, the soft tissue shrinks and stiffens. Within the scope of sleep surgery, interstitial radiofrequency (RFQ) has been established in the treatment of the inferior turbinates [77], the soft palate [78], and the base of tongue [79]. Less is known about its use in the treatment of tonsillar hypertrophy.

Currently, several systems are available which are distinguished from one another by the method of energy input they employ. The energy input can either be controlled or uncontrolled. The controlled procedures include the thermo-controlled somnoplasty (Somnus, Gyrus ENT, USA) and the Celon system (Celon AG Medical Instruments, Teltow, Germany) which controls the energy via the tissue resistance increase. Furthermore, a multitude of uncontrolled systems are available for interstitial radiofrequency surgery which induce energy as long as the surgeon wishes.

Surgery is usually performed under local anaesthesia. The needle electrode is inserted into the lymphatic tissue of the tonsil. Depending on the size of the tonsil, four to eight lesions are set. The amount of swelling in the initial postoperative period exceeds the initial reduction, which means that tonsil size may be equal or larger than the preoperative size. Therefore, radiofrequency technique shoud not been used on an outpatient basis in patients with kissing or almost kissing tonsils. Tonsil shrinkage occurs between the first and third week after surgery.

Efficacy for SRBD

The calculated reduction of the tonsil size is specified as 51.1% [80] to 75.0% [81]. Nelson described improvements in daytime sleepiness (79%) and subjective snoring (81%). These results remained constant after 6 and 12 months in the same population [82]. In children the same author found an improvement in quality of life variables 1 year after surgery.

Concerning the efficacy for OSA there are only two publications [80], [83]. Unfortunately, other surgeries had been performed simulanteously. This is why no conclusion can be drawn concerning the efficiency of isolated RFQ of the tonsils for OSA.

5.3. Soft palate

5.3.1. Uvulopalatopharyngoplasty (UPPP)

No surgical procedure for the treatment of SRBD has received more research attention than uvulopalatopharyngoplasty (UPPP). Since the first UPPP by Ikematsu in 1963 several procedures have been published, which aim at reducing the excessive tissue components of the soft palate without impairing the functions of the soft palate in swallowing and speaking. Radical procedures do not amend the surgical outcome but increase the incidence of postoperative complications [84]. When employing more radical techniques, as they were still being suggested in the 80ies, permanent velopharyngeal insufficiencies in up to 24% of cases [85], nasopharyngeal stenoses up to 4% [86], and nCPAP therapy failures as a result of oral leakage [16] have been described.

For 15 years a modification [87] of the technique originally introduced by Fujita in 1981 [88] is used which preserves the palatal muscles. With this technique no long-term velopharyngeal insufficiency or nasopharyngeal stenosis (as result of lateralization and forward relocation) has been observed in more than 600 patients. Today, in our opinion, *no* indication exists for a radical UPPP.

Efficacy for simple snoring

Numerous studies have been published regarding the efficacy of isolated UPPP for primary snoring. Here also the definitions of what constitutes surgical success differ immensely; in the following, only studies with long-term data are compiled. Follow-ups of at least 3 years were regarded as long-term data.

The existent studies include 868 patients [89], [90], [91], [92], [93], [94], [95], [96]. Combining the values for "snoring reduced" and "no snoring" results in a long-term success rate of 71% for isolated UPPP in the treatment of primary snoring. But this figure has to be considered with caution, due to the fact that the diverse evaluation criteria are extremely heterogeneous. Accordingly, the success rates vary in the cited studies between 44% and 91%. Two studies [90], [95] also include short-term results from the identical patient pool. Respectively 87% and 76% were classified as responders. This percentage fell in the long-term follow-up to respectively 46% and 45%. Accordingly Hassid et al. [96] recently described decreasing success rate with increasing follow-up periods.

It was possible to objectively corroborate a reduction of the alpha-EEG arousals after UPPP in the case of non-apneic snoring [97]. Janson and colleagues [98] found reductions in daytime sleepiness and fatigue in 155 nonapnoic snorers following UPPP.

Comparison of different soft palate surgical techniques

Chabolle and colleagues [91] included in the same follow-up study also patients after LAUP. With 44%, the success rate (complete elimination or satisfactory reduction of snoring) was identical in both groups. But the general satisfaction with the surgery was significantly higher in the UPPP group than in the LAUP group.

An objective analysis of the respiratory sounds during sleep furnished a similar success rate for UPPP and LAUP, both for short-term (2-11 months) and long-term (29-56 months) follow-up assessment [99], [100].

Lysdahl and Haraldson [101] prospectively performed UPPP or LUPP in 121 patients. UPPP was superior to LUPP for all clinical effect parameters. Similarly, in the study of Hagert and coworkers [93] the conventional UPPP yielded significantly better results for snoring than LUPP.

Efficacy for OSA

Only few prospective studies exist covering long-term results of up to 9 years after UPPP. As with the other techniques, the comparability of these data is made problematic due to varying success criteria. Almost unanimously, all authors find a discrepancy between adequate subjective improvement of their symptoms and nearly unchanged objective sleep parameters after UPPP. Therefore, a polygraphic or polysomnographic postoperative evaluation is necessary after one to three years.

Every surgeon should study the excellent survey by Sher et al. 1996 [76]. The authors used as success criteria an AHI < 20 *and* a reduction of the AHI of at least 50% (or analogously: AI < 10 *and* AI reduction > 50%). For the non-selected patient pool this meta-analysis yielded a surgery success rate of 40.7%. In the selected group with clinically suspected obstruction solely on the level of the soft palate, a success rate of 52.3% was found. For the most part, these data are based on short-term results.

Data concerning long-term success are available for 99 patients in 6 publications [92], [102], [85], [103], [104], [105], which impressively demonstrates that the effect of UPPP on the severity of OSA decreases over the years. As a consequence of these findings, we and other study groups infer the necessity of a long-term sleep study control of the patients after UPPP. The employed success criteria are again heterogeneous. If one combines those data, which use Sher`s success criteria [76], this yields a long-term success rate of 49.5% for isolated UPPP including tonsillectomy in the treatment of OSA. Nowadays one can rightly assume a positive long-term effect of isolated UPPP, possibly in connection with a tonsillectomy.

In accordance with these results, in a group of 400 patients with SRBD who had received a UPPP or a laser UPP no increase in mortality was found in comparison to a control group comprised of 744 persons [106]. These data may indicate a positive survival effect of UPPP surgery. Keenan et al. [107] contacted their OSA patients treated with either UPPP (N=149) or nasal CPAP (N=126) over a 6-year period to compare long-term survival rates between these two treatments. There was no difference between the two treatment groups. Furthermore, UPPP for SRBD turned out to improve the patients' stimulated long-term driving performance [108] and decreased the number of car accidents within a five year period after surgery [109].

5.3.2. Laser-assisted procedures

As an essential modification of the conventional UPPP technique laser-assisted modifications were developed. Various different techniques have been introduced. We recently divided the techniques into three basic concepts [110], [111], [112], [113], [114]. According to our experience we see the most advantages in a cautiously performed modified Kamami technique [110]. As in UPPP surgery it is crucial to avoid aggressive surgery. Otherwise serious complications like nasopharyngeal stenosis or nasopharyngeal incompetence occurs. Both complications are difficult to correct.

Efficacy for simple snoring

Up to now there are no generally accepted techniques to quantify snoring. In the literature either visual analogue scales (VAS) usually filled out by the patients' bed partner, or so-called snoring indices (SI) based on different algorithms analyzing the recorded snoring sounds during sleep studies are used to describe the efficacy of LAUP for simple snoring. Others use simple questionnaires with items like "Do you still snore?" to verify treatment success.

Relevant data from prospective studies using VAS to evaluate the subjective improvement of LAUP for simple snoring are given in Table 2 (Tab. 2). Extremely varying definitions of success complicate the interpretation of the results.

Concerning the efficacy for simple snoring there are no substantial diffenences between the three basic techniques. About three quarters of the patients benefit from laser surgery in the short-term run. In general 2 to 3 treatment sessions are needed to achieve a satisfying reduction of snoring. However as after UPPP, patients' satisfaction decreases over time [114], [115], [116], [117], [118]. Sufficient long-term data are still lacking. Only Osman and colleagues [100] found a statistically significant reduction in the snoring index in the long-term follow-up 29 to 56 months after surgery using objective assessment of snoring sounds.

The results comparing conventional UPPP and laser-assisted surgery of the soft palate have already been discussed. As compared to radiofrequency treatment laser surgery again showed comparable results in regard to the subjective reduction of snoring. But laser surgery induced significantly more postoperative pain [119], [120], [121], [122].

Efficacy for OSA

In 2000 we conducted a metanalysis on the efficacy of laser surgery to the soft palate for OSA [123]. At the time, there were no long-term results. Today more substantial information exists. There are polysomnographic data about 321 patients [124], [125], [126], [127], [128], [129], [130], [131], [132]. The over-all success rate is a disappointing 27.7%. Medium-term results (> 8 months of follow-up) are substantially worse than short-term results [133]. Controlled studies [130], [131] imply that LAUP is more effective than doing nothing but much less effective as conventional UPPP for OSA.

The present data support the statements of the Standards of Practice Committee of the American Academy of Sleep Medicine [134], that laser-assisted surgery of the soft palate is not recommended for the treatment of obstructive sleep apnea and in particular that it is not recommended as a substitute for UPPP.

5.3.3. Radiofrequency surgery (RFQ)

Today, radiofrequency systems have been established which need 3 to 6 thermic lesions to achieve a treatment effect. Surgery is usually performed under local anaesthesia as an outpatient procedure on the sitting patient. Up to four treatment sessions are needed to achieve a maximum reduction of snoring sounds.

Efficacy for simple snoring

In 1998 Powell et al. [78] first reported the use of interstitial radiofrequency surgery for the human soft palate in the treatment of simple snoring. We recently summarized the results in a meta-analysis [135].

The studies providing results of subjective snoring (visual analogue scales or snoring index) were summarized in terms of two meta-analyses. In those studies using the visual analogue scales a total number of 505 patients were treated [78], [121], [136], [137], [138], [139], [140], [141], [142], [143], [144], [145], [146]. The weighted mean score of these studies was reduced from 8.2 to 3.7. The mean weighted treatment effect was 4.5. In those studies using the snoring index a total number of 167 patients was treated [147], [148], [149], [150], [151], [152]. The weighted mean ± SD was reduced from 8.1 to 3.3 and the weighted mean treatment effect was 4.8. The changes in mean snoring scores of the average score of the studies involved was significant at a level of $p < 0.01$.

Again, similar to the results after UPPP or laser surgery of the soft palate, at longer follow-up a relapse over time was seen in 11% to 41% of the patients [138], [141], [146]. In contrast to other techniques radiofrequency surgery offers the possibility to treat the patients again with radiofrequency surgery.

Terris et al. [143] compared interstitial radiofrequency surgery of the soft palate with LAUP in a prospective, randomized manner. LAUP revealed a slight advantage over radiofrequency but resulted in a greater degree of postoperative discomfort.

Recently we finished a placebo-controlled, prospective trial. Each 15 primary palatal snorers received either an isolated radiofrequency surgery of the soft palate or a sham operation. In the latter the applicators were inserted into the soft palate but no energy was delivered. For the whole group of individuals we received comparable results to the meta-analysis stated above with a significant reduction in snoring severity (VAS). However, there was no superiority of RFQ surgery compared to the control group. These newest results question the often reproduced significant effect of RFQ of the soft palate on simple palatal snoring. However, these results need to be confirmed.

Efficacy for OSA

There are only two studies dealing with isolated interstitial radiofrequency at the soft palate for OSA [153], [154]. Although the reductions in mean AHI were statistically significant both studies, there is only very little information that interstitial radiofrequency treatment of the soft palate might be effective for mild OSA.

5.3.4. Other procedures

Uvulopalatal flap

Uvulopalatopharyngoplasty (UPPP) is a relatively time-consuming surgical procedure, even in the case of sufficient surgical experience and practice. This fact has contributed to the interest generated by a modification, the uvulopalatal flap, developed at Stanford [155]. Today we prefer a further modification of the original technique with lateral extension to the tonsil bed, which impresses by its simple and fast mode of executing without sacrificing the advantages of UPPP [156].

Concerning the efficiency of the uvulopalatal flap for the treatment of sleep-related breathing disorders only few data have been published. Only one publication addresses the therapy of primary snoring [157]. Both a subjective and objective reduction of the snoring sounds could be demonstrated in 65 primary snorers 14 months after surgery.

More data exist concerning the efficiency of the uvulopalatal flap for the treatment of OSA [156], [158], but still the amount of data is extremely limited compared to the data available for the UPPP. But since the surgical techniques are very similar in their principles, it seems justified in assuming that the weak data situation is sufficient to posit a comparable efficacy of the uvulopalatal flap with the UPPP in the treatment of OSA.

Palatal implants

Recently, a new minimally-invasive procedure that places cylindrical implants within the soft palate has been introduced recently [159]. This anti-snoring implant consists of polyethylenterephthalat (PET). The material has been used as vascular endoprosthesis, as mesh in stomach surgery, and in heart valves. All in all, three rod-shaped implants are inserted in the soft palate. The implants itself and the surrounding scarring induce a stiffening of the soft palate; in order to reduce or eliminate snoring.

As in the case of LAUP and interstitial radiofrequency surgery of the soft palate, this technique is performed on an outpatient basis in the sitting patient under local anesthesia. The implants are delivered in a hollow needle. The complete hand piece is a disposable instrument.

Up to now, no data exist for OSA. For simple snoring its few short-term results are comparable with interstitial radiofrequency surgery of the soft palate [160]. Soft palate implants directly compete with this procedure. Longer follow-up intervals will have to show whether one of these two minimally invasive techniques will turn out to be preferable.

Uvulectomy

Uvulectomy is no adaequate treatment option for sleep disordered breathing. There is no rationale for resections of soft palate muscles. Mortimore et al. [16] demonstrated that in the case of a CPAP therapy after an isolated uvulectomy already for low respiratory pressures oronasal air leaks occur; these can make an effective respiratory treatment impossible.

Palatal stiffening operation

Ellis et al. [161] investigated the mechanics of snoring in the laboratory as an aid for devising a more effective operation. These studies have shown that there are several methods by which snoring can be generated, but that palatal flutter is probably the most important factor. The dominant parameters in the generation of flutter of the palate are its length and stiffness. Any removal of tissue to shorten the palate as in UPPP inevitably risks impairing its function. Therefore, the authors were the first to choose the stiffening alternative. Using a laser, a central longitudinal strip of mucosa was removed from the surface of the soft palate which healed by fibrosis, producing the required stiffening.

Other working groups adopted this technique using electrocautery to remove the anterior palatal mucosa in order to achieve palatal stiffening. Mair and Day [162] remove a 2 cm central palatal mucosal flap under local and topical anesthesia. Throughout the operation the palatal muscles remains intact. By week 2 or 3, the palate is stiffened.

This technique is recommend for primary snoring as well as for mild forms of OSA [162], [163]. At short-term follow-up 190 simple snorers (92%) reported successful reduction or elimination of snoring. Follow-up evaluation 6 to 36 months postoperatively (mean 12 months) revealed a drop in the success rate to 77.

In mild OSA the success rate using Sher criteria [76] was estimated as 48% three months after surgery, which is quite similar to conventional UPPP.

Injection snoreplasty

Injection snoreplasty was introduced in 2001 to treat palatal snoring [164]. The surgical concept consists of the injection of sclerosing agents into the soft palate. As a result, scarring ensues a stiffening of the soft palate. The authors initially used 3% sodium tetradecyl sulfate (STS) as an effective agent. In Europe, this substance has not been approved for this usage. In a recent publication, further agents were assessed in respect to their efficacy [165]. None of the tested substances produced better results than STS. Only 50 % ethanol was found to produce equivalent subjective and objective snoring efficacy and equivalent pain and recovery time compared to STS. However, a higher rate of transient palatal fistula was found in the case of ethanol.

The data are limited in their scope by the fact that they stem from merely one study group, and only encompass a small number of patients. At short-term follow-up the efficiency for simple snoring is stated as 92% after 1.8 treatment sessions on average [164]. 19 monthzs after surgery the success rate dropped to 75% [166].

Transpalatal advancement pharyngoplasty

Evaluations of pharyngeal properties before and after UPPP, using both computerized tomography and acoustic reflection, have demonstrated increases in oropharyngeal size and decreases in oropharyngeal collapsibility. Larger increases in these characteristics are associated with a successful clinical response to UPPP [167]. Woodson and Toohill [168] concluded from these findings that in some patients technical failure may occur, and introduced a new surgical alternative to UPPP, the so-called transpalatal advancement pharyngoplasty (TAP).

The surgical principle consists in not only altering the inferior edge as in a UPPP, but also in advancing the base of the soft palate at the hard palate. This entails a partial resection of the posterior edge of the hard palate. Surgery is performed under general anesthesia. All together 10 patient underwent an isolated TAP procedure. The success rate according to Sher was 70% [168], [169].

The TAP is a treatment modality for OSA, especially for those patients who still show a narrow retropalatal airway after a UPPP.

5.4. Tongue base and hypopharynx

5.4.1. Radiofrequency surgery (RFQ)

RFQ therapy of the tongue base can easily be performed under local anesthesia with sedation [170]. Using a special needle device between 8 and 16 lesions per session, depending on the size of the tongue base and the radiofrequency system used. One to 2 therapy sessions are needed (mean 1.8).

Efficacy for simple snoring

Up to now, there are no studies investigating the effect of isolated interstitial radiofrequency surgery of the tongue base for simple snoring. At least snoring subjectively improved after isolated tongue base RFQ in patients with OSA [171].

Efficacy for OSA

While in 2001 the use of RFQ at the base of tongue was still regarded as not thoroughly enough assessed, today sufficient data exists concerning its efficiency in OSA. The applied total energy amounts vary from 7915 J [79], [172] to 13394 J [173]; yet no clear correlation between applied total energy amount and surgery result can be deduced.

For altogether 108 patients [79], [171], [173], [172], [174] polysomnographic data exist, indicating a surgical short term success rate employing Sher criteria of 33.5% for RFQ of the tongue base for (on average) moderate OSA. However, the data need to be cautiously interpreted. This is due to the fact that the study design of the RFQ studies is a very different one. In all of the other procedures, a sleep lab evaluation is performed before and after the therapy. But in the case of the RFQ treatments, therapy continues until the polysomnography produces a satisfactory result. This is the issue at stake: the polysomnography exhibits a high night-to-night variance, which in this case only becomes evident in a positive manner for the surgery result [175], [176]. In other words: we doubt that the presented results would be corroborated by a therapy design delineated from the start by a defined number of sessions, lesions, and a defined amount of energy input.

A careful reading of the raw data in the cited studies indicates that mainly mild forms of OSA are suitable for a therapy with RFQ at the tongue base. With RFQ for the first time a minimally-invasive and effective procedure for the tongue base is at disposal. The postoperative morbidity and complication rate is strikingly low. Therefore RFQ at the tongue base can be regarded as a very significant broadening of the surgical therapy spectrum.

5.4.2. Hyoid suspension

The idea to prevent the collapse of the tongue musculature, which relaxes during sleep, towards dorsal into the upper airway with the help of a suspension of the hyoid bone is not new. Already at the beginning of the 80ies a widening of the upper airway after hyoid suspension was demonstrated, first for the animal model [177], [178], and later for humans [179]. Initially it was attempted to fixate the hyoid on the chin.

Today, the hyoid is suspended to the thyroid cartilage. This technique requires less dissection and turned out to be as effective as the original technique [180]. Surgery is usually performed under general anesthesia [181], although as an isolated procedure it can be done under local anesthesia as well [182].

Efficacy for SRBD

Hyoid suspension is a surgical technique which up to now has only been suggested for the treatment of OSA. Currently, no published data exist in regards to its usefulness for primary snoring.

Also in regards to the efficacy in the therapy of OSA the data for isolated hyoid suspension are rare due to the fact that the hyoid suspension is almost always performed together with a mandibular osteotomy with genioglossus advancement (MO). Only Riley et al. [180] presented results of an isolated hyoid suspension in 15 patients with OSA. The success rate was estimated as 53.3% according to Sher`s criteria. Furthermore, hyoid suspension has established itself as an essential and effective therapy element in the context of multi-level concepts for moderate to severe OSA. [183].

5.4.3. Other procedures

Tongue base resections

Before in the mid-nineties, in the form of RFQ, a minimally invasive surgical procedure at the tongue base was available for the first time, already several surgical concepts existed for the volume reduction of the tongue via an open resection. In those cases where surgery was performed on the tongue base a temporary tracheotomy often became necessary in order to secure the upper airway. A further problem was posited by painful swallowing impairments, which often lasted three and more weeks. As a result, these surgical techniques were always reserved for the severe cases of OSA which could not be treated with respiratory therapy. But even today very few individual cases exist where such an invasive procedure can be indicated.

Surgery is performed under general anesthesia. In principle, a transoral approach for tongue base resections in the midline area is conducted [184]. Most authors rely on the CO_2-laser [185], [186], [187]. In contrast to these transoral techniques Chabolle and coworkers [188] use a transcollar approach.

Due to the high postoperative mobidity tongue base resections are reserved for severe OSA. It is notable that the results range between 25% and 80% success rate (Sher criteria). Altogether, data of only 68 patients are available; 22 of these data sets stem from retrospective analyses. The data situation can therefore be only regarded as provisional, and only allows for a cautious inference. It appears that some patients with severe OSA due to a hypopharyngeal collapse do indeed profit from a partial tongue resection, especially if clinically only a macroglossia is manifest [187].

Tongue suspension

In the case of an absence of other anatomical abnormalities, such as skeletal malformations or tongue base tumors, snoring can be caused by a falling back of the tongue during sleep. During the daytime, this phenomenon is prevented by the voluntary motor system. Already in 1992, based on this observation that snoring can be caused by a falling back of the tongue during sleep a glossopexy was suggested in which the tongue base is fixated at the chin with the help of a tissue sling in order to prevent a collapse towards posterior as a result of the physiological muscle relaxation during sleep [189] (Figure 2 (Fig. 2)).

Yet this method has gained renewed currency with the introduction of the Repose® system (Influ-ENT, USA), characterized as minimally-invasive [190]. It is comprised of a surgical kit which includes, apart from surgical instruments, a non-absorbable suspension suture which is passed through the tongue base and then fixated with the help of a screw at the inner cortex of the chin. In contrast to the RFQ therapy of the tongue base the Repose® system is a method requiring general anesthesia; we therefore consider it to be minimally-invasive only to a certain degree.

Data for primary snoring stem from two multi-center studies [191], [192] which apparently to some extent contain the same patient data. According to these studies the Repose® system is successful in the short-term run in the therapy of snoring in the case of clinically attested tongue base constriction.

More study data are available for OSA. The mean values for pre- and postoperative AHI as well as for the surgical success rate after Sher are almost identical with those after isolated radiofrequency therapy at the tongue base. Both techniques are used for the same indication, namely clinically evident obstruction at the tongue base level, and apparently both techniques are comparable in regards to their efficacy.

Unfortunately the repose system has two fundamental drawbacks compared to RFQ treatment. On the one hand, general anesthesia is necessary to place the suspension suture. Secondly, it is quite difficult to achieve the correct tightness. Aim of the suspension suture is to prevent airway collapse during sleep without impeding the function of the tongue during the day, as speaking and swallowing. The concrete disadvantage of the method lies in the lack of a postoperative option to readjust the tightness. For this readjusting a second general anesthesia is necessary.

5.5. Maxillofacial surgeries

Genioglossus advancement

In 1986, the inferior sagittal osteotomy of the mandible was used for the first time in the treatment of OSA by the Stanford research group [193]. Since then the so-called mandibular osteotomy with genioglossus-advancement (MO) has become part of several surgical protocols. Interestingly, the technique has until now only been used in combination with other techniques and not as an isolated procedure for treating OSA.

The genioglossus muscle has its origin at the oral side of the mandible. The surgical principle consists in mobilizing the whole area of this muscle insertion by incorporating the genial tubercle on the inner cortex via an osteotomy of the chin, and then moving it towards anterior. In this new position the bone segment is fixated osteosynthetically. External cortex and cancellous bone are removed in order to prevent a cosmetically disagreeable protrusion of the chin.

Maxillo-mandibular advancement (MMA)

Maxillofacial surgery for the correction of malpostion of the upper and lower jaw was first suggested by Kuo et al. [178] as an alternative to tracheotomy in the treatment of OSA. The rationale of MMA is the simultaneous expansion of the naso-, oro-, and hypopharyngeal airways as soft palate, tongue, and lateral pharyngeal walls are advanced or stretched. Although MMA is a routine procedure in maxillofacial surgery, it is technically demanding and performed by a team of surgeons in a hospital environment under general anesthesia [194].

MMA can be considered the most successful surgical procedure for the treatment of OSA after tracheotomy with respect to treatment outcome. Several controlled studies have demonstrated a comparable reduction of the AHI after MMO to CPAP therapy [195], [196], [197], [198], [199], [200], [201], [202]. Furthermore, an equivalent optimization of the sleep architecture compared to CPAP has been reported after MMA [203]. The successful results seem to be maintained for long follow-up periods. The Stanford studies report a short-term success rate of 97% after 6 months [196], and a success rate of 90% after 51 months [204].

Today, maxillomandibular advancement (MMA) can be seen as the most successful surgical procedure after tracheotomy. On the other side it must be said that it is an invasive surgical technique with corresponding morbidity and complication rates. Therefore, it is used as primary therapy in patients with relevant deformities of the face and the skull in most instances. For sleep apneics without a jaw anomaly the Stanford 2 phase concept has become the standard treatment. In phase 1 it offers a multi-level surgery of the soft palate and tongue base, and if necessary of the nose; only in the case of therapy failure does it offer MMA as a secondary procedure.

Distraction osteogenesis (DOG)

Since its introduction into maxillofacial surgery by McCarthy et al. in 1992 [205], distraction osteogenesis (DOG) has become an accepted procedure in the treatment of severe maxillomandibular deficiency in syndromic and non-syndromic patients. As a grossly retropositioned mandible or midface causes a narrow pharyngeal airway, OSA is often found in these cases. Thus DOG will be the procedure of choice where conventional MMA cannot be performed or is expected to lead to unstable results. This is especially true for neonates and young children in whom MMA is rarely performed [206].

By now most publications on DOG in OSA patients include only small numbers or are case reports. Concerning neonates or children exact polysomnographic pre- and postoperative data are not given in the majority of reports. However, avoiding or ending tracheostomy is the major treatment objective in this patient group and DOG is the most effective procedure.

5.6. Multi-level surgery

A multi-level procedure for the surgical therapy of OSA was presented for the first time in 1989 by Waite and colleagues [207]. The authors combined nasal surgery with a UPPP, tongue surgery, a mandibular osteotomy with genioglossus advancement (MO), and a maxillomandibular advancement osteotomy (MMO). Basically, the classification of the upper airway into different levels of obstruction stems from Fujita [19], who distinguished between retropalatal, retrolingual, and combined retropalatal and retrolingual obstruction. On the basis of this distinction Riley et al. [208] defined the term and concept of multi-level surgery. In the meantime, first studies have been published concerning virtually every possible combination of soft palate and tongue base procedures.

Multi-level surgery is also performed on children with severe OSA on the basis of various primary illnesses in order to avoid an otherwise necessary tracheotomy [209], [210], [211].

Surgical concepts

Efficacy of minimally-invasive multi-level surgery for mild to moderate OSA

Of the procedures employed, only the isolated RFQ therapy can be regarded as a minimally invasive technique. The data are still very sparse [83], [212]. It only seems possible to deduce two trends. On the one hand, the combined treatment of tongue base plus soft palate does not appear to significantly improve the results of an isolated tongue base treatment in respect to the AHI. Secondly, RFQ surgery appears to be limited to cases of mild OSA with an AHI of maximally 20. This trend is corroborated by the results of the currently single existing placebo-controlled study on this topic [213].

Efficacy of multi-level surgery for moderate to severe OSA

On the level of the soft palate, invasive therapy concepts include either a UPPP or a uvulopalatal flap, both with tonsillectomy. For the treatment of the hypopharyngeal obstruction different procedures have been recommended. Altogether, data of 764 patients from retrospective studies and from prospective case control studies exist [182], [184], [200], [202], [208], [214], [215], [216], [217], [218], [219], [220], [221], [207], [222], [223], [224]. For the present study situation this results in a grade III evidence according to the criteria of the Canadian task force on periodic health examination. The success rate according to Sher et al. [76] lies at 54%. With the exception of the study by Nelson [220], the studies dealt with on average severe forms of OSA. A sufficient amount of data exists to validate the efficacy of multi-level surgery in the case of severe OSA.

Up to now it not possible to decide which combination is the most efficient one. It is probably up to the surgeon to find out which techniques he can mange best.

6. Conclusions

By now, there a quite a few different reconstructive procedures to correct impaired pharyngeal breathing. Figure 3 (Fig. 3) illustrates the indications in dependence of the severity of the SRBD for the different treatment modalities discussed in this review.

By now, as the authors own opinon there is no indication for the following procedures: uvulectomy, injection snoreplasty, cautery assisted palatal stiffening operation, transpalatal advancement pharyngoplasty, and tongue suspension procedures. Based on criteria of evidence based medicine there is no indication for the patal implants as well, although there is some excellent experience in this field.

All kind of soft palate surgeries seem to partially loose their efficacy with increasing time. In contrast procedures addressing other anatomical regions produce stable results.

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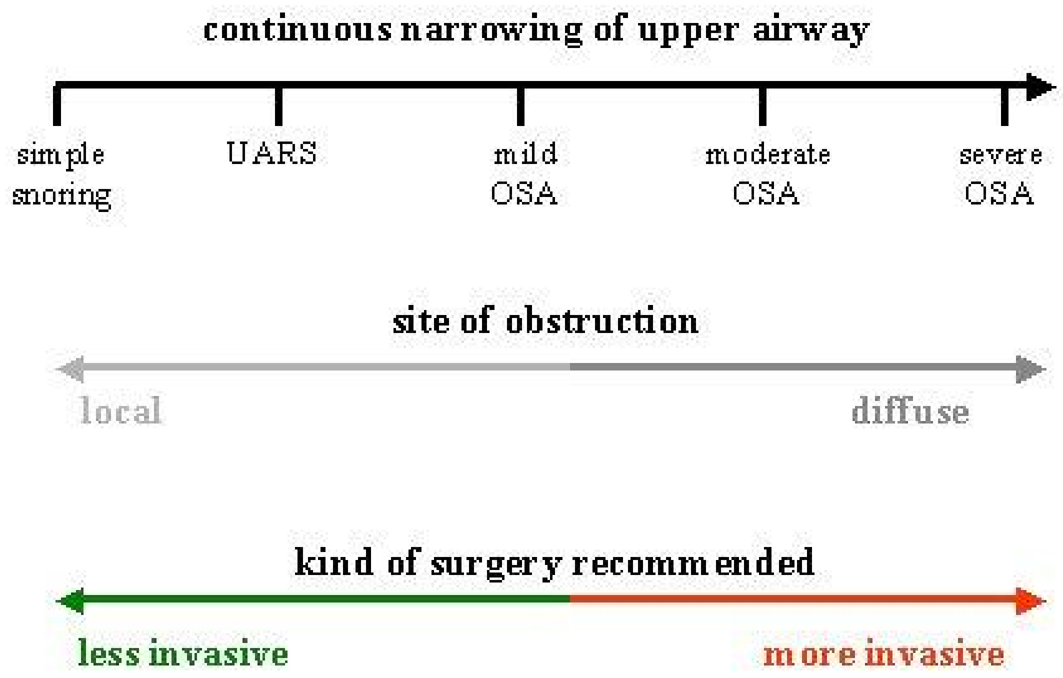

Figure 1: Continuous narrowing of upper airway modified after Moore [1]

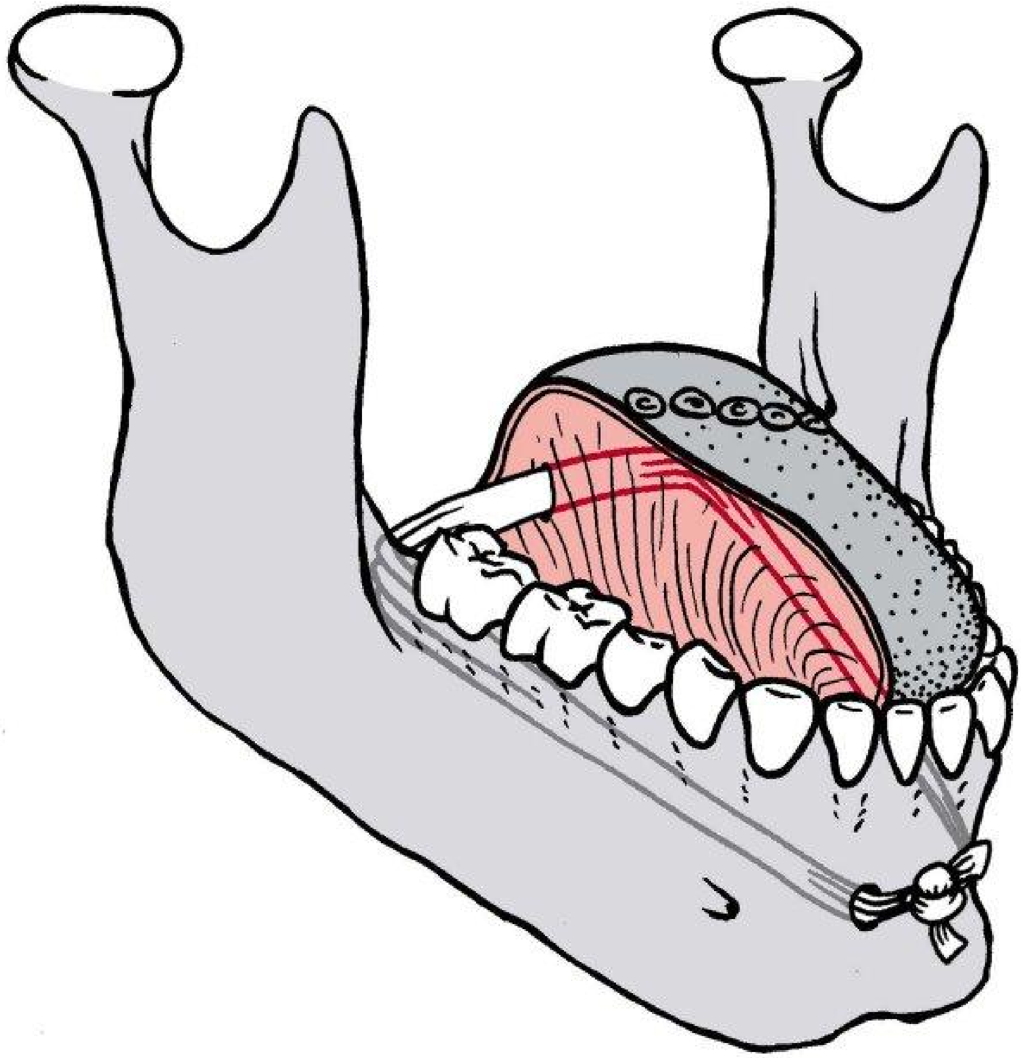

Figure 2: Original technique of glossopexy with fascia lata modified after Faye-Lund et al. [189]

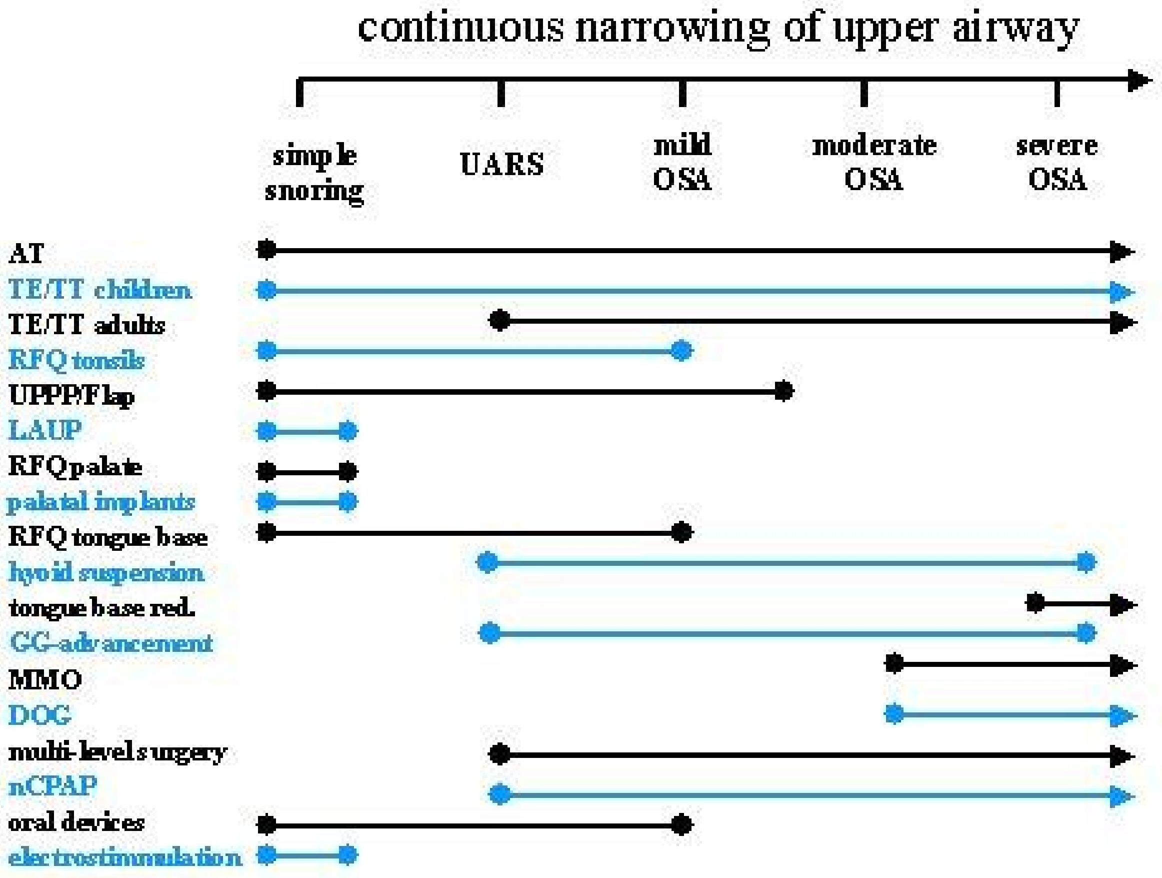

Figure 3: Indications for different reconstructive procedures within the pharyngeal upper airway in the treatment of SRBD

technique	during sleep	quantification	disadvantages	clinical routine
pressure measurements in the upper airway	+	+	SE, limited life-span of the expensive probes	+
flexible nasopharyngoscopy	+	(+)	SE, mom	+
analysis of the respiratory sounds	+	+	SE	(+)
cinefluoroscopy	+	+	rad, mom	-
rapid CT scans	+	+	rad, mom	-
radiocephalometry	-	+	rad, mom	+
acoustic reflexions	+	+	SE	(+)
rapid MRI scans	+	+	Mom (up to 1 hour)	-

Table 1: Techniques for objective localization of upper airway narrowing. SE: special expert knowledge necessary; mom: detects only short periods of sleep; rad.: exposure to radiation

Author	N	Follow-up [months]	VAS	Success rate [%]	Def. of success	Laser	EBM
LUPP							
Albu et al. [232]	90	no data	0 to 10	80	VAS < 4	Nd:YAG	II-2
Carenfelt [111]	60 (36)	3 – 4	1 to 4	85 (89)	Red. > 1	CO_2	II-1
Wennmo et al. [233]	10	2 – 36	1 to 3	80	VAS ≤ 1	CO_2	II-2
all	**160**	**2 - 36**		**83.4**			
MST							
Ellis [114]	14	3 (15 –18)	1 to 10	87.5 (66)	VAS < 4	Nd:YAG	II-2
Shehab et Robin [234]	24 (27)	3 - 52	1 to 10	79.2 (81.5)	Red. > 2	CO_2	II-1
Morar et al. [235]	25	6	1 to 100	24 (68)	Red > 90% (Red ≥ 25%)	CO_2	II-2
all	**85**	**3 - 18**		**76.8 (60.4)**			
LAUP							
Hanada et al. [236]	35	1	1 to 10	51.4	Red > 50%	Nd:YAG	II-2
Vukovic et Hutchings [237]	25	6	0 to 12	84	VAS ≤ 6	CO_2	II-2
Walker et al. [238]	105	1.5	0 to 100	60	Red > 70%	CO_2	II-2
Astor et al. [239]	38	no data	0 to 7	76.3	VAS < 4 and Red > 2	CO_2	II-2
Schlieper et al. [240]	152	12	1 to 6	88	VAS ≤ 3	CO_2	II-2
all LAUP	**355**	**1 - 12**		**74.6**			

Table 2: Efficacy of LAUP for simple snoring. VAS: visual analogue scale; Red: reduction; LUPP: laser uvulopalatoplasty; MST: mucosal strip technique; LAUP: laser-assisted uvulopalatoplasty