Barbed Pharyngoplasty and Sleep Disordered Breathing

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ISBN 978-3-030-96168-8 ISBN 978-3-030-96169-5 (eBook)
https://doi.org/10.1007/978-3-030-96169-5

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

To my wife Daniela, wonder woman, and to my formerly "kids" Francesca, Enrico and Maria, my beloved "home" family; to all my dear hospital and university assistants, residents, and fellows, to me as one more family.

Claudio Vicini

To my wife Maria Giovanna, the real point of reference for my whole life and career; to all my precious teachers and colleagues, in particular to Fabrizio Costantini, "historian" and irreplaceable friend and support to my profession.

Fabrizio Salamanca

To my girlfriend Daniela, support of my daily life; to my mother Maria Antonietta, my father Pasquale, and my sister Emilia who have always believed in me; to my nephew Alessandro who reminds me to smile every day.

Giannicola Iannella

Foreword

To write a foreword for this book, I have been asked to remember how the knowledge of Sleep Disordered Breathing has developed over the years in Italy; this is because I was the first to take an interest in this subject from the early 1980s.

Back in the 1970s, young physicians were assigned the meticulous task of continuously checking the international journals in their specialty (Index Medicus e l'Exepta Medica) in search of new bibliographical information to share with the team. By doing so, early in my career, I came across a novel work about a disorder, unknown to me at that time, known by the acronym OSAS (Obstructive Sleep Apnea Syndrome). I was fascinated by this condition, often discussed by neurologists as a neurologic problem (sleep disturbance), but substantially involving the upper airways. What amazed me was the fact that the manuscripts almost exclusively discussed the sleep disorders, and although it was somehow related to the presence of obstructive problems in the upper airways, the root cause of the obstruction was not investigated or discussed at that time. From my ENT point of view, I started to wonder what could be the possible anatomic sites and modalities of the obstruction(s) leading to the apnea and sleeping disorders.

In 1972, Prof. Lugaresi, a neurologist and sleep expert at the University of Bologna (Italy), was the first to realize that sleep alterations due to breathing pauses were due to upper airway obstruction. He convinced his ENT colleagues to perform a tracheotomy on two OSAS patients to bypass the obstruction. The results were outstanding; at the control polysomnography there was no more evidence of apnea with normalization of the trace. We will need to wait for another decade for further therapeutic updates, with a work published in *Lancet* in 1981 by Dr. Sullivan, a pneumologist, who was the first to propose ventilatory therapy with CPAP in OSAS patients.

In Europe, the first ENT specialists to perform surgical therapy for OSAS were Drs. Quesada and Perellò in Barcelona, and later Drs. Swartz and Chabolle in Paris in the mid-1980s, as well as a few specialists in Germany, England, and Holland. It was only in the mid-1980 that I started to perform uvulopalatoplasty surgery following Quesada and Perellò's approach.

In 1991, I organized in Italy, in collaboration with a colleague pneumologist, the first Congress on OSAS with the participation of Drs. Fujita, Quesada, and Perellò, and where the young Dr. Salamanca presented for the first time a report on Muller's maneuver, reporting on the cutting-edge use of videoendoscopy to better evaluate the nature of the obstruction.

In Italy it is only in the mid-1990s that ENT specialists began to develop an accurate and increasingly refined semeiotics of videoendoscopy in awake patients, starting a work of classification of the various sites of obstruction of the VAS together with an increasingly precise definition of the type of obstructive event (e.g., antero-posterior, latero-lateral, circular). The ENT began a long process of training that saw the emergence of Prof. Vicini (Forlì, Italy) as the main opinion leader in the field. He was the first to codify the different procedures by establishing the indications for a multilevel surgery and not only limited to the palatal level.

Prof. Vicini gave an important contribution to the affirmation, in the late 1990s, of the UP3 technique (Uvulopalatopharyngoplasty) in which we started to be more conservative, with respect to the muscular plane and a suture that provided for the eversion of the mucosa of the posterior face of the palate towards the oral cavity. In addition, more attention was beginning to be paid to the suturing of the tonsillar pillars. This was creating favorable conditions for a new surgical approach more respectful of the central quadrant of the palate with preservation of the uvula and a surgery that gradually began to move to the lateral walls.

Sleep endoscopy is also an important part of the history of OSAS. It was developed only in the past 15 years; it played a critical role to characterize the level of obstruction leading to a more accurate and increasingly personalized therapeutic approach.

We are now in the new millennium and thanks to the contributions of Drs. Cahali, Tucker Woodson, Pang, and Vicini, we have arrived at the BRP (Barbed Reposition Pharyngoplasty) without forgetting the fundamental contribution of Dr. Mantovani in collaboration with Dr. Salamanca for having introduced the use of barbed sutures, which proved to be of fundamental importance in ensuring the success of BRP. This book will further describe this innovative and important surgical approach.

As for the future of OSA surgery, we are in very good hands, thanks also to the group of internationally recognized and dedicated surgeons who have authored this important book.

Lecce, Italy — Michele De Benedetto
Rome, Italy

Foreword

This foreword is dedicated to the memory of Mario Mantovani who died suddenly in July 2020.

He spent his clinical career in the Department of Otolaryngology—Head and Neck Surgery at the Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico of Milan. He specialized in ENT, ophthalmology, reconstructive plastic surgery, and maxillofacial surgery at the University of Milan.

He started as an assistant in 1974 under the guidance of Professor Ettore Bocca, who awarded him the position of Adjunct Professor, and subsequently continued to work under my direction from 2007 until July 2020.

He was the author of many book chapters as well as numerous scientific papers published in peer-reviewed journals.

He was a learned gentleman, passionate about his profession, a lover of life, and a brilliant inventor of new devices such as the "antral retriever" for the removal of foreign bodies from the maxillary sinus.

He developed innovative surgical approaches for the treatment of obstructive sleep apnea—modular barbed snore surgery and obstructive sleep apnea-hypopnea syndrome (OSAHS) surgery—and was the first to use barbed sutures for pharyngoplasties. This pioneering approach changed the current surgical management of sleep apnea worldwide.

The purpose of this book is to describe this new surgical approach to the most common problems in patients with sleep disordered breathing, an approach which is no longer based on resection but on the creation of force vectors that can offset the pathological collapse of airway walls.

This modern physiopathological interpretation has radically changed OSAHS surgery from enlarging the upper airway lumen by resection, as in the case of uvulopalatopharyngoplasty, which does not always guarantee satisfactory results and is characterized by high postoperative morbidity, to increasing the static tension of the upper airway walls.

In 2010, we started to imagine the upper airway as a complex structure consisting of two coaxial tubes, the first a rigid outer tube of static bony and fibrous tissue and the second a soft inner tube characterized by two components: a passively static component consisting of the mucosa and submucosa, and a second dynamic component consisting of the upper airway muscles whose activity continuously depends on neural control modulated by the central nervous system. On the basis of these considerations, Mario Mantovani had the idea of transferring the rigidity of the outer tube to the inner tube exactly where and how it is needed by using intratissutal threads and a custom-made surgical approach, with the second aim of slightly increasing the basal tension.

For all of us his death was a sad and immense loss. He will remain in the memory of all those who had the privilege of knowing him and be remembered in the history of the surgical approach to sleep and OSAS disorders.

It is my hope that this book will help sleep surgeons find a reliable path through the complex and fascinating world of snore surgery and be the starting point for developing further new and minimally invasive surgical techniques.

I am grateful to the editors for their support in planning and realizing this project.

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Preface

Palate Surgery: The Never-Ending Story

The first specifically devised palate procedure for snoring and obstructive sleep apnea was described in the 1980s by Fujita. The key to the **technique** named uvulopalatopharyngoplasty (UPPP) was the planned trimming of a long drooping palate under general anesthesia. Though UPPP is really painful and somehow dangerous, it was for many years the workhorse for sleep surgeons all over the world, and until recent years it was identified as the "prototypal" sleep surgery procedure. In the 1990s, laser **technology** changed the palate sleep surgery. Laser-assisted uvulopalatoplasty (LAUP) by Kamamy and Krespy made palate surgery easier and possible under local anesthesia and in outpatient settings. In the late 1990s, a different **technology** based on radiofrequency volume reduction paired up with LAUP and was widely popularized as a painless and multistep outpatient option for snoring and OSA by Powell and Coll. More or less in the same period, the same Stanford Group described an original conservative **technique** for the same purposes. The uvulopalatal flap (UPF) did not require any special equipment, and it was theoretically reversible. Last but not least, among the innovative **technologies** proposed for snoring palate management, the so-called Pillar Procedure was devised, based on the insertion of a polyester implant into the soft palate. The magic decade between 2000 and 2010 produced a large group of innovative techniques based on different and original solutions. Lateral palatoplasty **technique** by the pioneer Cahali moved the attention to the stabilization of the lateral pharyngeal wall. The Tucker Woodson and Pang **technique** optimized the same concept reverting the action of Orticochea sphincter pharyngoplasty for velopharyngeal insufficiency. The Friedmann Z-palatoplasty **technique** applied the general concept of any Z-plasty to the special problem of a narrow palatopharyngeal area. Finally, Dr. Li from Taiwan devised an elegant **technique** for relocation of the palatopharyngeal muscle in order to increase pharyngeal stability.

The decade between 2010 and 2020 is featured by the introduction into the palate surgery of a special knotless **technology** of suture: the barbed suture. Dr. Mantovani, a brilliant ENT and plastic surgeon, developed the idea to transfer the experience of barbed wire face-lift with the reabsorbable barbed sutures into the "palate lift" for snoring and OSA. This basic idea spread inside the Milan area and branched into many different **techniques** which were devised, applied, and described at the Policlinico under the guidance of Prof. Lorenzo Pignataro and at the Humanitas San Pio X Hospital—Milan by Fabrizio Salamanca, an enthusiastic leader of a group of young sleep surgeons. The seed of the new idea was accepted almost at the same time by a second group of sleep surgeons in Forlì, where a new palate **technique** of Barbed Reposition Pharyngoplasty was developed by Prof. Vicini, introduced into practice, and carefully studied, as well as exported into many countries around the world.

The first aim of the present monograph may be considered our grateful tribute to Mario Mantovani for his clever ideas and for his never-ending effort to share this basic concept.

The second aim of our job is an attempt to organize in a comprehensive way the many published papers and moreover the great number of unpublished data about barbed palate surgery for sleep disordered breathing, as we routinely perform it in our institutions.

Forlì, Italy Claudio Vicini
Milan, Italy Fabrizio Salamanca
Rome, Italy Giannicola Iannella

Contents

1 Evolution of Palatal Surgery for Sleep-Disordered Breathing

Hsueh-Yu Li, Li-Ang Lee, Ming-Shao Tsai, and Shih-Chieh Shen

1.1 Introduction

Obstructive sleep apnea (OSA) is a chronic and prevalent disease associated with major adverse cardiac events, neurocognitive impairments, obesity, and other morbidities [1–4]. Mainstream therapy for OSA includes continuous positive airway pressure (CPAP), oral appliance, and surgery [5, 6]. CPAP is the first-line and gold standard for OSA. However, modest acceptance and low long-term compliance limit the application of CPAP in OSA patients [7]. Surgery is an alternative and salvage treatment for patients who are unwilling or intolerant to CPAP therapy [7]. Furthermore, surgery is the only treatment modality to improve OSA without the use of a device. Among various sleep surgeries, UPPP was the first surgical procedure specifically designed to treat snoring and OSA [6]. Traditional UPPP includes

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_1

tonsillectomy and excision of the redundant pillars, soft palate, and uvula [6]. Although improvement in clinical symptoms, UPPP was criticized for its unacceptable pain, high complications, and low success rate [8]. Therefore, modification of UPPP has been undergoing in the past four decades. The first part of this article elaborates on the historical evolution of palatal surgery regarding key differences in surgical procedures from time to time. Conceptual evolution is then discussed in terms of surgical indication (why to treat), obstruction site (how to diagnose), and treatment endpoint (when to stop). Technical evolution dives into details of cutting-edge and state-of-the-art surgical techniques. Finally, the evolution of postoperative care is emphasized on enhanced recovery after surgery and integrated treatment to fulfill the quality of care and long-term outcomes.

1.2 Historical Evolution

1. *On the horizon*. Resection of the soft palate triangle paramedian to the uvula has been implemented for snoring in the 1950s [9, 10]. Amputation of the uvula (uvulectomy) was performed to ameliorate snoring in the 1970s [11]. Theses techniques implied the critical relationship between the velum and snoring, which inspired following palatal surgeries.
2. *In-between*. Tracheostomy via permanent stoma was the model treatment of Pickwickian syndrome and OSA with severe daytime sleepiness in the 1960s [12, 13]. However, related comorbidities and the development of non-invasive CPAP therapy prohibit its clinical use [14].
3. *Origin*. UPPP developed by Fujita in the 1980s was the surgical milestone in treating snoring and OSA [6]. Traditional UPPP aimed to enlarge and stabilize the oropharyngeal airway and consequently prevented its collapse. Simmons advocated removing the soft palate as much as possible to maximize airspace and that became a stereotype of UPPP (classic UPPP) [15]. Clinical outcomes of UPPP revealed significant improvement of subjective symptoms in conjunction with incongruous changes in polysomnography [16].
4. *Mini-invasive procedure*. Laser-assisted uvulopalatoplasty (LAUP), utilizing a CO2 laser to vaporize the vibrating uvula and soft palate, led to a series of office-based anti-snore procedures in the1990s [17]. Despite LAUP improved habitual snoring in the short term, the residual fibrotic palatal tissue narrowed the velopharyngeal airway and exacerbated OSA. Radiofrequency was introduced as interstitial thermotherapy to the soft palate without major complications in the late 1990s [18]. The caveat of RF was that it might require repetitive treatments to achieve desirable results due to decayed effects over time [19]. Pillar implant was introduced to stiffen the soft palate via a single application in the early 2000s [20]. It could reduce snoring in primary snorers; however, a comprehensive treatment approach was required to tackle more severe SDB patients [21].
5. *Reconstruction of the lateral pharyngeal wall (pharyngoplasty)*. Several modifications of the UPPP technique were implemented to prevent airway collapse by stabilizing the lateral pharyngeal wall. Procedures such as lateral pharyngoplasty,

expansion sphincter pharyngoplasty, Z-palatoplasty, and relocation pharyngoplasty had been published in the 2010s [22–25].

6. *Suspension technique*. More palatal procedures attempted to further enlarge the velopharyngeal airspace by suspending the palatopharyngeus muscle to the pterygomandibular raphe. Barbed Roman blinds technique, barbed anterior pharyngoplasty, barbed reposition pharyngoplasty, suspension palatoplasty, barbed suspension pharyngoplasty, and omni-suspension were proposed in recent years [26–32].

1.3 Conceptual Evolution

Conceptual changes of palatal surgery for OSA could be discussed in three perspectives: the surgical aim (why to treat), obstruction site (how to diagnosis), and treatment endpoint (when to stop).

Surgical Aim *not only for OSA but holistic care of comorbidities*

OSA is a chronic and age-related disease; surgical intervention for OSA is more likely to improve than cure the disease. Evidence showed that palatal surgery for OSA significantly alleviated clinical symptoms, prevented cardiovascular disease, improved disease severity but rarely cured it [8, 33–35]. Recent evidence revealed that OSA patients had a higher prevalence of vertigo, tinnitus, sudden deafness, normal-tension glaucoma, infection rate, Alzheimer's disease than the matched non-OSA population [36–39]. Therefore, the purposes of palatal surgery are to improve quality of life, lessen disease severity, ameliorate comorbidities, and prevent major complications in OSA patients. In addition, morbid obesity may not be absolute surgical contraindication if combined airway and bariatric surgeries are considered to improve both OSA and obesity.

Obstruction Site Evaluation *not only DISE but interventional DISE*

Traditional assessments of the airway obstruction are implemented in wakefulness, which cannot reflect the obstruction site during sleep [40]. Drug-induced sleep endoscopy (DISE) simulates the dynamic changes of the airway during pharmacologically induced sleep, and identification of obstruction sites of the airway becomes accessible. Therefore, DISE reasonably becomes one of the prerequisites in surgical planning for OSA patients [41]. Conversely, the effectiveness of palatal surgery in the setting of multi-level surgery for OSA remains unclear due to the complexity of aerodynamic interactions between different domains of the upper airway, such as velopharyngeal, oropharyngeal, and hypopharyngeal spaces. Interventional DISE by placing a nasopharyngeal tube during exam demonstrated that 74% of patients had partial improvement, and 35% had complete collapse resolution [42]. Reductions in the collapse were observed at sites of the lateral wall (86%), epiglottis (55%), and tongue base (50%) [42]. This finding supported that the patency of retropalatal airspace could potentially reduce negative pharyngeal pressure and alleviated other upper airway obstruction sites. As a result, interventional DISE can provide a tailor-made surgical plan for OSA patients with or without multi-level obstructions.

Surgical Endpoint *not only AHI but comprehensive and preventive effect*

Typically, the success or failure of sleep surgery for OSA is judged by changes in AHI pre- and postoperatively [8]. However, OSA is a chronic disease associated with other comorbidities; thus, it is more realistic to intervene and improve sleep apnea in a timely fashion than pursue a statistical cure. Also, research has revealed that the change in AHI is not always consistent with the improvement of clinical symptoms, which are patients' primary concerns. Therefore, the reasonable goal in treating OSA should be to improve the disease in terms of AHI reduction, ameliorating symptoms, and minimizing unfavorable clinical outcomes. In summary, the endpoint of palatal surgery for OSA is suggested as follows: (1) significant improvement of clinical symptoms (snoring and daytime sleepiness), (2) correction of OSA severity to "mild" (AHI < 15/h), (3) decreased profile of biomarkers indicating risks of coronary artery/cardiovascular diseases [43, 44], and (4) patient's satisfaction of surgical results.

1.4 Technical Evolution

Through excision of the "redundant" soft palate, classical UPPP incurred severe postoperative pain and velopharyngeal insufficiency that further jeopardized salvage use of CPAP in surgical failure patients due to mouth leak [15, 45]. Studies showed that the lateral pharyngeal wall collapse was the crucial factor contributing to OSA [46]. To address this issue, the technical evolution of palatal surgery initially started as "functional reconstruction" of the lateral pharyngeal wall, which included lateral pharyngoplasty [22] and relocation pharyngoplasty [25], for example. However, suboptimal stabilization/expansion of the velopharynx resulted from the reconstructive-driven procedures because of the lack of structural support of the velum. Therefore, the evolution of palatal surgery transitioned to the concept of "suspension," which suspended the pharyngeal muscle, especially the palatopharyngeal muscle, to the pterygomandibular raphe as the anchor [29]. The Barbed Roman blinds technique was first introduced [26, 27], and a series of Barbed variants were developed to cope with different patterns of palatal obstructions [28–31].

Furthermore, the thesis of tissue-specific hybrid surgery was postulated based on the suspension technique. Physiological hybrid palatal surgery could be constructed following histologic gradation: (1) mucosa: preservation, (2) lymphoid tissue: excision, (3) adipose tissue: ablation, and (4) muscle: suspension [47] (Fig. 1.1). Preservation of the mucosa is crucial to facilitate wound healing, lessen suture tension to reduce wound dehiscence, and maintain submucosal gland secretion to prevent dryness of the mouth. Tonsil is the only tissue to be excised to widen the oropharyngeal space and facilitate the lateral pharyngeal wall reconstruction. Also,

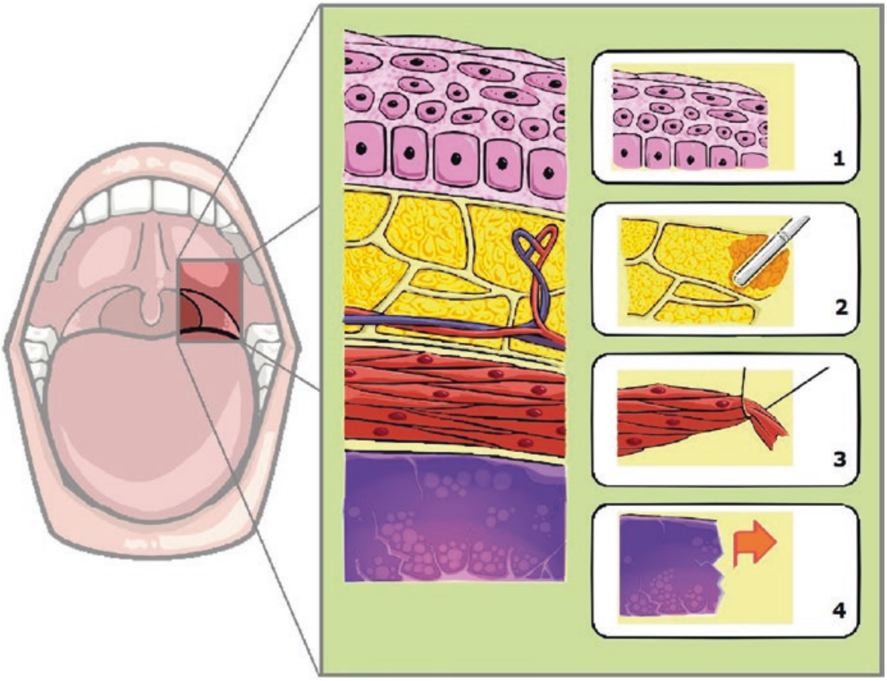

Fig. 1.1 Tissue-specific hybrid surgery. (1) mucosa: preservation, (2) adipose tissue: ablation, (3) muscle: suspension, (4) lymphoid tissue: excision

deposition of redundant adipose tissue at the periuvular area and supratonsillar fossa can narrow the velopharyngeal airspace and impede the suspension procedure of pharyngeal muscles. Ablation of pharyngeal adipose tissue can be implemented in supratonsillar fossa after tonsillectomy via electrocautery (cutting mode) under assistance of endoscopy and in thick soft palate (thickness > 1 cm) via radiofrequency or coblation (ablation mode 5). Suspension of pharyngeal muscle via omni-suspension technique is pivotal in the hybrid reconstruction of palatal surgery. Omni-suspension involves stay suture of the palatopharyngeus muscle, figure-of-eight styled bundle suture of the pterygomandibular raphe, suspending the muscle to the raphe, and three suspension sutures toward anterior, middle, lateral directions [32] (Fig. 1.2). Noteworthy, omni-suspension is particularly helpful in OSA patients with concentric velopharyngeal collapse during DISE examination.

1.5 Postoperative Evolution

Postoperative inpatient care following palatal sleep surgery generally involves the delivery of humidified oxygen, positional therapy by elevating the cranial end of the bed, prophylactic antibiotics, analgesics, and ice packing on the submental area [48]. A comprehensive therapy program, Enhanced Recovery After Surgery

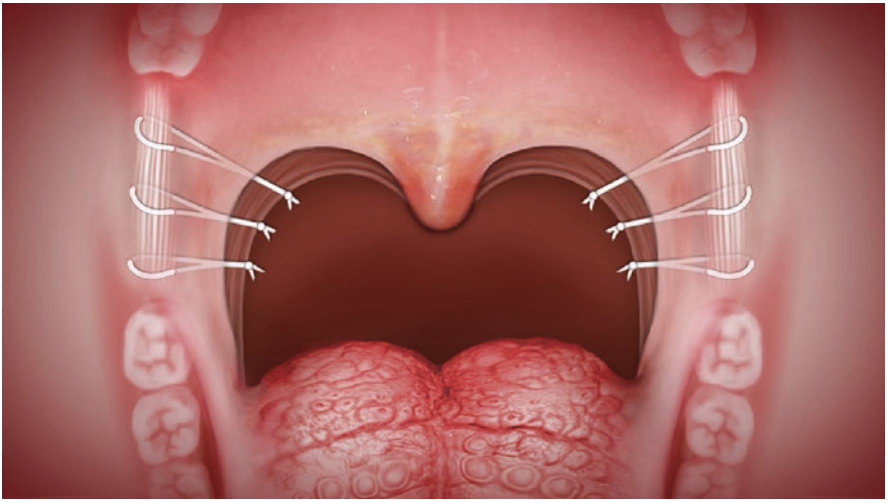

Fig. 1.2 Omni-suspension by suspending the palatopharyngeus muscle to pterygomandibular raphe, three suspension sutures toward anterior, middle, lateral directions

(ERAS), has been proposed for head and neck surgery and sleep surgery to improve the quality of postoperative care [49, 50]. The ERAS for sleep surgery is a multidisciplinary measure composed of preoperative education, lifestyle adjustment (cessation of smoking and alcohol, if any), adequate nutritional support, evaluation of carbohydrate and body fluid intake, cooperation with anxiety, postoperative pain management of multimodal analgesics, and early swallowing rehabilitation and ambulation. Research showed a significantly lower overall complication rate and incidence of fever in ERAS-applied pediatric OSA patients undergoing adenotonsillectomy [50]. Furthermore, pediatric patients with ERAS reported less postoperative pain, had a better dietary intake, and were found with lower preoperative anxiety scores [50]. These suggested that the ERAS program could reduce physical and psychological burden perioperatively in OSA patients.

It is not uncommon that the clinical outcome of palatal surgery may be compromised over time owing to aging, circadian rhythm sleep disorders (delayed/advanced sleep phase disorder, sleep deprivation, shift work sleep disorder) [51], open mouth breathing, supine sleeping position, and increased body weight. Therefore, integrated treatment is much needed to enhance short- and long-term outcomes. Avoidance of delayed sleep phase or sleep deprivation is essential to maintain the physiological muscle tone of the soft palate and tongue, which in turn counteracts the collapsibility during sleep. In addition to the effects of palatal suspension procedures, the retropalatal airspace is further stabilized by the constant airflow from the nasal cavity through the velopharynx during sleep. Therefore, it is crucial to control nasal obstruction, prevent open mouth breathing (possibly taping the mouth), and apply oropharyngeal myofunctional therapy to facilitate nocturnal

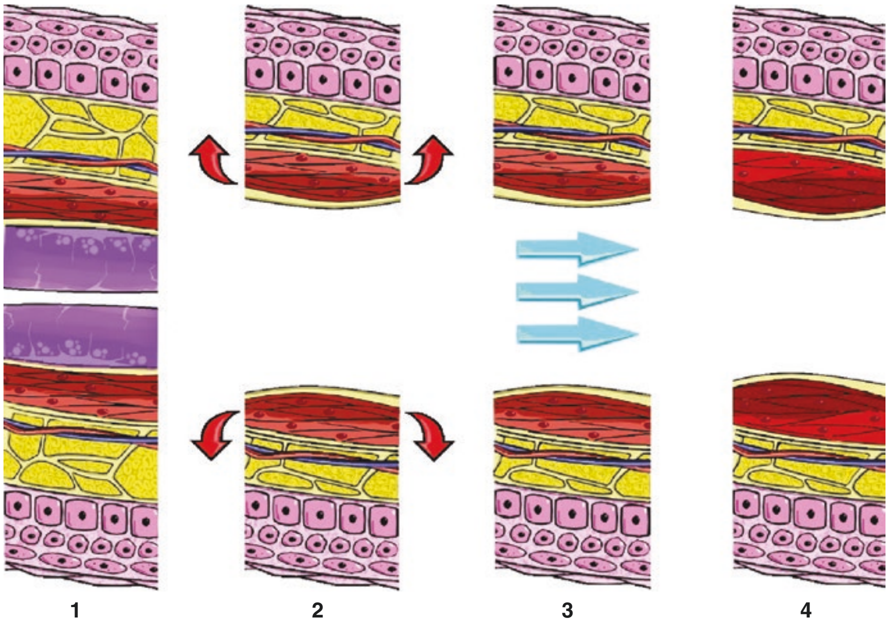

Fig. 1.3 Demonstration on integrated treatment after palatal surgery from baseline velopharyngeal obstruction, hybrid reconstruction of the velopharyngeal airway, restoration of the velopharyngeal airflow, to integrated re-habilitation of the oropharyngeal muscle

nasal breathing [52, 53]. Positional therapy (lateral sleeping position) also can reduce snoring and sleep apnea by enlarging and maintaining the lateral dimension of the retropalatal space postoperatively [54]. Bodyweight reduction is beneficial for cardiopulmonary function, and the airspace can be less obstructive by the reduction of pharyngeal fat [55]. Figure 1.3 illustrates the overview of integrated treatment of palatal surgery for OSA: (1) baseline velopharyngeal obstruction, (2) hybrid reconstruction of the velopharyngeal airway, (3) restoration of the velopharyngeal airflow, and (4) rehabilitation of the oropharyngeal muscle.

1.6 Summary

In this article, the evolution of palate surgery was discussed in terms of concept, technique, and postoperative care. The palatal surgery remains the key procedure in treating snoring and OSA, and the suspension of the pharyngeal muscle enlarges and further stabilizes the velopharyngeal airspace. The chapter on palatal surgery is still evolving, rooting from physiological hybrid surgery and combined operation, multidisciplinary integrated treatment, and ultimately to the holistic care for OSA patients.

Acknowledgments The author would like to express the deepest gratitude to Linkou-Chang Gung Memorial Hospital for long-term support by grants in our sleep research. The authors also thank Dr. Yi-Chan Lee, Dr. Chien-Han Tsao, and Dr. Ying-Shuo Hsu for their extensive consultation to this chapter.

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2 The New Generation of Palate Surgery for Obstructive Sleep Apnea

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2.1 Introduction

Obstructive sleep apnea (OSA) is categorized under the sleep disordered breathing continuum ranging from simple snoring to OSA. OSA due to upper airway collapse arising from pharyngeal and tongue muscle relaxation during sleep results in hypoxemia with increased sympathetic overdrive, increased blood pressure, and hypercapnia. The stoppages in breathing would result in arousals from sleep and sleep disruptions causing sleep fragmentation leading to excessive daytime sleepiness, tiredness, lethargy, morning headaches, poor concentration, fatigue, poor memory, and irritability.

Most sleep specialists have shown a strong correlation between OSA and hypertension, atherosclerosis, and cerebrovascular accidents (strokes) [1]. Studies have also shown a higher mortality rate among patients with cardiovascular disease who also have OSA [1]. Therefore, it would be reasonable to say that early and effective treatment of OSA is of great essence.

Treatment of OSA can range from nasal continuous positive airway pressure (CPAP) as the "gold" standard, to oral appliances, to upper airway surgery. Upper

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_2

airway surgery has evolved and improved significantly over the past 10–20 years [2–12]; however, the concept of surgical success has not changed much during this period (50% reduction and/or AHI apnea-hypopnea index (AHI) <20) [13].

In the 1960s, Quesada and Perello [14] introduced the more ablative technique of treating snoring by the removal of the uvula and soft palatal soft tissue. Forty years on, new palatal techniques have been introduced; in the early 2000s, Michel Cahali [15] introduced the lateral pharyngoplasty which had promising results, while Pang and Woodson introduced the expansion sphincter pharyngoplasty [16], which showed far better outcomes for patients with lateral pharyngeal wall collapse.

The basic fundamentals of the new generation of palate surgeries are:

(a) to address the exact anatomical site of collapse,
(b) preserving the mucosa and soft tissues,
(c) while respecting muscle and anatomical function of each structure.

Coupled with these newer palatoplasty techniques, one must not forget the introduction of more comprehensive methods for airway evaluation. Drug induced sleep endoscopy (DISE) has changed the reality of what the airway is when asleep versus when awake. Studies have shown that the treatment plans of patients with and without DISE performed are markedly changed in over 60–70% of patients [17–20] (whether they had DISE performed before their surgery).

The authors discuss the systematic review of the medical literature and meta-analysis of papers on upper airway palate surgery for OSA between the years January 2001 and February 2018 and review the success rates of palate surgery over the past 17 years.

2.2 Methodology

A comprehensive systematic literature review using searches of MEDLINE, Google Scholar, Cochrane Library, PubMed, and Evidence Based Medicine Reviews to identify publications relevant to OSA treatment and upper airway palate surgery with its variants. All relevant studies published between January 2001 and December 2017 were included.

The authors looked at surgical outcomes and results, with the inclusion criteria being:

1. ***Patients:*** adults, more than 18 years of age, with AHI > 5.
2. ***Comparison:*** quantitative data pre- and post-palate surgery.
3. ***Outcomes:*** including either success rates of treatment, pre-operative and post-operative AHI, Epworth sleepiness scale (ESS), quality of life (QOL), and/or snoring visual analog scale (VAS).
4. ***Study design:*** published, peer-reviewed studies with at least a 3 month follow-up period post-surgery.

5. ***Intervention***: palatal surgery involving either the soft and/or hard palate, lateral pharyngeal wall, palatopharyngeus, with or without tonsil surgery and/or uvular procedure. The authors excluded (a) procedures performed in addition to palate surgery (i.e. tongue surgery, skeletal surgery), (b) LAUP, (c) studies with qualitative outcomes only, (d) patients who had previous upper airway surgery, and (e) patients who have central sleep apnea.

The following combined search terms were used on PubMed and MedLine (using both British and American spellings): "upper airway surgery and sleep apnea/obstructive sleep apnea," "palate surgery and sleep apnea/obstructive sleep apnea," "airway modifications and sleep apnea/obstructive sleep apnea," "pharyngoplasty and sleep apnea/obstructive sleep apnea," "palatoplasty and sleep apnea/obstructive sleep apnea," "tonsil surgery and sleep apnea/obstructive sleep apnea," "systematic review and sleep apnea/obstructive sleep apnea," and "meta-analysis and sleep apnea/obstructive sleep apnea."

A total final number of 59 articles were identified and included. The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement and checklist were followed as much as possible during this review.

The authors analyzed the pooled results (pre-operative and post-operative) of all palate procedures performed on the entire group of OSA patients. The authors also looked at the results (pre-operative and post-operative) of the three main categories of palate procedures (namely lateral/expansion palatal procedures, anterior palatal procedures, and the classic uvulopalatopharygoplasty).

2.3 Statistical Method

Meta-analysis was conducted using the Cochrane Review Manager (version 5.3), (The Nordic Cochrane Centre, The Cochrane Collaboration). Random effect models are used to generate pooled estimates. Data was analyzed using generic inverse radiance method and $p < 0.05$ is regarded as statistically significant. Combined summary statistics of the standardized (STD) paired difference in mean for the individual studies are shown. Combined STD paired differences in means were calculated and a 2-sided p-value <0.05 was considered to indicate statistical significance. An χ^2-based test of homogeneity was performed and the inconsistency index (I^2) statistic was determined. If I^2 was >50% or >75%, the studies were considered to be heterogeneous or highly heterogeneous, respectively. If I^2 was below 25%, the studies were considered to be homogeneous. If the I^2 statistic (>50%) indicated that heterogeneity existed between studies, a random effects model was calculated. For the second part, due to the high heterogeneity in each subgroup ($I^2 = 91.4\%$ $p < 0.001$, $I^2 = 89.8\%$ $p < 0.001$, and $I^2 = 95.0\%$ $p < 0.001$, respectively), a random effects analysis was performed using the DerSimonian and Laird method. In order to check the differences in the reduction on AHI between each surgical technic, Z-scores have been computed. A p-value <0.05 has been considered statistically significant. The entire meta-analysis was carried out using "Stata IC 12.1."

2.4 Results

The PubMed/Medline database search revealed 2103 papers, 945 papers were not relevant, a further 802 did not meet the inclusion criteria; 243 papers were on multi-level upper airway surgery, 99 papers were subsequently excluded for they did not document pre- and post-surgery AHI, finally, 14 papers were not included as they lacked documentation of follow-up duration, leaving 59 papers [15–73] that met the inclusion criteria.

There were a total of 59 scientific papers included for analysis. All these papers met the inclusion criteria and reported their results in a clear and concise way. A total of 2694 patients underwent a varied number of palatal surgery types that included the traditional uvulopalatopharyngoplasty (UPPP), Han modified UPPP, uvulo-palatal flap (UPF), extended UPF (EUPF), modified extended UPF (MEUP), Z-palatoplasty (ZPPP), lateral pharyngoplasty (LP), relocation pharyngoplasty (RP), expansion sphincter pharyngoplasty (ESP), anterior palatoplasty (AP), functional expansion sphincter pharyngoplasty (FESP), limited palatal muscle resection (LPMR), barbed anterior palatoplasty (BAP), partial palate resection (PPR), soft palatal webbing flap palatopharyngoplasty (SPWF), barbed Roman blinds technique (BRBT), barbed repositioning pharyngoplasty (BRP), anterolateral advancement pharyngoplasty (AAP), and the barbed expansion sphincter pharyngoplasty (BESP) (Table 2.1).

The authors showed that many sleep specialists/surgeons have moved away from the traditional UPPP and/or its modified variants. Ever since the introduction of the Cahali [15] LP in 2003 and the Pang et al. [16] ESP in 2007, most surgeons have adopted and utilized the newer innovative techniques to address the lateral pharyngeal wall collapse and anterior–posterior soft palatal narrowing.

Over the past 18 years (January 2001 to February 2018), the authors described that (in these 59 papers) the uvulopalatopharyngoplasty technique only accounted for 16.7% of all the 2715 pooled patient procedures performed.

Interestingly, from January 2001 to December 2010, the percentage of UPPP procedures were 25.6% (264 out of 1034), and from January 2011 to February 2018, the percentage of UPPP procedures were only 12.6% (213 out of 1681).

From the 59 papers analyzed, there were 2715 patients who had upper airway surgery and met the criteria. The average follow-up was 8.18 months (range 6 to 54 months). The mean decrease in AHI (pre- to post-procedure) was from 35.66 to 13.91 ($p < 0.001$). The mean decrease in ESS (pre- to post-procedure) was from 11.65 to 5.08 ($p < 0.001$). The mean AHI change was 19.9 (SD 8.32, range of 4.9 to 36.9) ($p < 0.001$). The mean ESS change was 5.8 (SD 2.2, range of 2 to 10) ($p < 0.001$). The overall pooled success rate was 67.5% (the range of success rates was from 25% to 94.1%).

After having divided the procedures into the three main categories, the meta-analysis of the respective palate procedure showed that the surgical technique that achieved the better reduction on AHI was the anterior palatoplasty, with a mean reduction of 24.7 (range 20.79–28.6) ($p = 0.015$), while the mean reduction

Table 2.1 Table with the 59 articles; traditional uvulopalatopharyngoplasty (UPPP), Han modified UPPP, uvulo-palatal flap (UPF), extended UPF (EUPF), modified extended UPF (MEUP), Z-palatoplasty (ZPPP), lateral pharyngoplasty (LP), relocation pharyngoplasty (RP), expansion sphincter pharygoplasty (ESP), anterior palatoplasty (AP), functional expansion sphincter pharyngoplasty (FESP), limited palatal muscle resection (LPMR), barbed anterior palatoplasty (BAP), partial palate resection (PPR), soft palatal webbing flap palatopharyngoplasty (SPWF), barbed Roman blinds technique (BRBT), barbed repositioning pharyngoplasty (BRP), anterolateral advancement pharyngoplasty (AAP), and the barbed expansion sphincter pharyngoplasty (BESP), modified radiofrequency tissue ablation (MRFTA)

	Author	Ref.	Year	*N*	Technique	Type	F-UP (months)	AHI pre	AHI post	Success rate (%)	ESS pre	ESS post
1	Cahali	15	2003	10	LP	Lat	8.2	41.2	9.5	60	13	5
2	Li et al.	17	2003	33	EUPF	AP	6	41.6	12.5	81.8	n.a.	n.a.
3	Cahali et al.[a]	18	2004	15	LP	Lat	7.9	41.6	15.5	53.3	14	4
				12	UPPP	Clas	8.2	34.6	30.0	41.7	14	5
4	Friedman et al.	19	2004	25	Z-PPP	Lat	6	41.8	20.9	68	12.5	8.4
				25	UPPP	Clas	6	33.4	25.2	28	14.2	8.7
5	Li et al.	20	2004	105	EUPF	AP	12	43.8	15	80	n.a.	n.a.
6	Li et al.	21	2004	55	EUPF	AP	6	43.6	21.1	82	11.8	7.5
7	Li et al.	22	2004	84	EUPF	AP	6	46.5	14.6	n.a.	11	7.2
8	Han et al.	23	2005	68	Han-UPPP	AP	6	32.1	12.7	69.1	10.1	4.5
9	Li et al.	24	2005	50	EUPF	AP	6	44.5	13.4	84	n.a.	n.a.
10	Hofmann et al.	25	2006	47	UPPP	Clas	4	8.0	5.0	n.a.	n.a.	n.a.
11	Li et al.	26	2006	110	EUPF	AP	6	44.4	15	78.2	n.a.	n.a.
12	Lin et al.	27	2006	55	EUPF	AP	6	43.6	12.1	82	11.8	7.3
13	Pang and Woodson[a]	16	2007	23	ESP	Lat	6	44.2	12	82.6	n.a.	n.a.
				22	UPPP	Clas	6	38.1	19.6	68.1	n.a.	n.a.
14	Huang and	28	2008	50	MEUP	AP	6	37.9	6.1	80	9.8	5.2
15	Li and Lee	29	2009	10	RP	Lat	6	43.4	15.7	50	9.6	6.3
16	Lundkvist et al.	30	2009	158	UPPP	Clas	12	27.2	10.8	64	12.0	6.0
17	Pang et al.	31	2009	77	AP	AP	33	25.3	11.0	71.8	16.2	7.9

(continued)

Table 2.1 (continued)

	Author	Ref.	Year	*N*	Technique	Type	F-UP (months)	AHI pre	AHI post	Success rate (%)	ESS pre	ESS post
18	Lee et al.	32	2011	30	RP	Lat	6	46.2	17.9	n.a.	10.8	6.5
19	Neruntarat	33	2011	83	UPF	AP	54	45.6	19.4	51.8	16.4	7.7
20	Mantovani et al.	34	2012	4	VUPL	Lat	6	15.5	n.a	n.a.	11.5	5.5
21	Choi et al.	35	2013	20	UPPP	Clas	3	37.2	20.1	n.a.	11.6	7.3
22	Li et al.	36	2013	47	RP	Lat	6	59.5	22.6	49	12.2	7.5
23	Browaldh et al.[a]	37	2013	32	UPPP	Clas	6	53.3	21.1	59	12.53	6.8
24	Kim et al.	38	2013	92	UFP+LP	Lat	6	39.1	7.9	78	11.1	6.6
25	Liu et al.	39	2013	51	Han-UPPP/ZP	Lat	6	65.6	29.5	45.1	12.8	5.5
				31	Han-UPPP		6	n.a	n.a	35.5	n.a.	n.a.
				20	Z-PPP		6	n.a	n.a	60	n.a.	n.a.
26	Marzetti et al.[a]	40	2013	19	UPF	AP	6	23	9.6	84	8.1	5.2
				15	AP	AP	6	22	8.6	86	8.5	4.9
27	Sorrenti and Piccin	41	2013	85	FESP	Lat	6	33.3	11.7	89.2	n.a.	n.a.
28	Yousuf et al.	42	2013	22	UPPP	Clas		43.1	13.2	95.2	n.a.	n.a.
29	Cho et al.	43	2014	23	LPMR	AP	6	32	5.6	n.a.	11.8	6
30	de Paula Soares et al.	44	2014	18	LP	Lat	6	33.5	20.9	50	n.a.	n.a.
31	Salamanca et al.	45	2014	24	BAP	Lat	6	8.9	3.8	n.a.	n.a.	n.a.
32	Ugur et al.	46	2014	42	AP	AP	24	13.2	7.1	51.7	11.5	8.3
33	Chen et al.	47	2015	32	RP	Lat	6	42.8	12.0	59.4	12.0	8.0
34	Chi et al.	48	2015	25	LP	Lat	6	34.1	17.3	n.a.	10.5	7.7

35	Carrasco-Llatas et al.	49	2015	22	PPR	Clas	7	47.2	18.4	72.7	n.a.	n.a.
				7	UPPP	Clas	7	47.3	12.0	71.4	n.a.	n.a.
				4	ZP	Lat	7	22.5	13.9	25	n.a.	n.a.
				10	LP	Lat	7	48.0	15.2	70	n.a.	n.a.
				10	ESP	Lat	7	27.7	6.5	90	n.a.	n.a.
36	Dizdar et al.	50	2015	14	LP	Lat	20	23.9	11.3	100	15.3	6.8
				9	UPPP	Clas	20	25.1	8.0	100	15.1	5.1
37	Elbassiouny	51	2015	28	SPWF	Lat	6	46	11	n.a.	n.a.	n.a.
38	Li et al.	52	2015	32	RP	Lat	6	18.3	5.9	n.a.	12.0	7.0
39	Li et al.	53	2015	60	RP	Lat	6	44.2	20.1	50	11.4	7.8
40	Mantovani et al.	54	2015	32	BRBT	Lat	12	36.9	13.7	84.4	15.3	5.7
41	Vicini et al.	55	2015	10	BRP	Lat	6	43.6	13.6	90	11.6	4.3
42	Emara et al.	56	2016	41	AAP	AP	6	42.1	16.3	87	16.3	8.1
43	Pang et al.	57	2016	73	AP+FESP	Lat	6	26.3	12.6	86.3	11.5	2.9
44	Sommer et al.[a]	58	2016	23	UPPP+TA	Clas	6	33.7	15.4	70	10.6	6.2
45	Wu et al.[a]	59	2016	24	UPPP	Clas	6	39.7	18.4	62.5	11.5	6.17
				24	UPPP-double suture	Clas	6	39.13	18.96	70.8	11.25	5.96
46	Adzreil et al.	60	2017	31	AP+TA	AP	12	35.0	18.5	32	13.3	7.1
47	Amali et al.[a]	61	2017	19	UPPP	Clas	6	20.15	10.03	77	12.07	6.87
				20	MRFTA	Clas	6	19.42	13.39	30	13.4	7.67
48	Askar et al.	62	2017	22	ESP-doublesuture	Lat	6	29.7	7.9	n.a.	12.3	4.6
49	Atan et al.	63	2017	14	AP+FESP	Lat	6	17.8	12.9	n.a.	n.a.	n.a.
50	Binar et al.	64	2017	23	FESP	Lat	6	32.36	11.79	69.6	11.82	5.21

(continued)

Table 2.1 (continued)

	Author	Ref.	Year	*N*	Technique	Type	F-UP (months)	AHI pre	AHI post	Success rate (%)	ESS pre	ESS post
51	Cammaroto et al.	65	2017	10	UPPP	Clas	6	37.8	22.9	50	12.3	8.5
				10	ESP	Lat	6	35.6	9.6	90	13	4.9
				10	BRP	Lat	6	34.04	13.5	90	10.4	3.9
52	Despeghel et al.	66	2017	35	FESP	Lat	6	41.3	17.4	53	n.a.	n.a.
53	El-Ahl et al.	67	2017	24	ESP-suspension	Lat	6	28.6	8.9	n.a.	11.7	5.1
54	Mantovani et al.	68	2017	19	ALIANZA	Lat	6	22.3	7	52	11.3	3.9
55	Montevecchi et al.	69	2017	111	BRP	Lat	6	33.4	13.5	73	10.2	6.1
56	Pianta et al.	70	2017	17	BESP	Lat	12	31.1	7.8	94.1	6	4
57	Rashwan et al.	71	2017	25	UPPP+TA	Clas	6	18.96	12.88	n.a.	8.8	7.34
				25	ESP	Lat	6	19.14	9.01	n.a.	8.96	4.12
				25	BRP	Lat	6	25.58	9.82	n.a.	9.28	3.76
58	Suslu et al.	72	2017	28	ESP	Lat	6	31	19.6	57	n.a.	n.a.
59	Plaza et al.	73	2018	75	ESP	Lat	12	22.1	8.6	69.3	11.5	4.7
	TOTAL			2715								
				2715			8.18	35.66	13.91	67.50	11.65	5.08

[a]Randomized controlled trials

of AHI for the lateral/expansion pharyngoplasty procedures was 19.8 (range 16.90–22.64) ($p = 0.046$), and the mean reduction of AHI for the classical uvulopalatopharyngoplasty was 17.2 (range 12.68–21.83) ($p = 0.360$).

2.5 Discussion

Since the late 1960s, the understanding and management of OSA have evolved and deepened. Sleep specialists widely accept that upper airway surgery can have good success rates for selected OSA patients who have favorable anatomical surgical structure. Most agree that the key to surgical success is patient selection, hence, clearer visualization of the airway during drug induced sleep endoscopy (DISE) [74–81] has enhanced the surgeon's ability to select the appropriate procedure for the appropriate patient.

Since the beginning of the early 2000s, DISE has enabled sleep surgeons to visually locate the exact anatomical site that collapses during the patient's sleep, hence, addressing that particular anatomical site. In addition, since 2003, the introduction of the LP [15, 18] and the ESP [16, 57, 82] in 2007, these 2 newer techniques have revolutionized the concept of sleep apnea surgery from ablative surgery to one that involves reconstruction while preserving the function of the uvula and sparing more mucosa.

Over the past 40 years, there has been an improvement in the success rates of palate surgery from 40.7% [8, 9], to 55% [83] to this current meta-analysis at 69.6%, in comparison to a systemic review by Rotenberg and Pang et al. [84], who reviewed 82 papers over a 20-year (1994–2015) CPAP treatment period, and demonstrated that the non-adherence rate of CPAP therapy remained high at 34% (plateau) throughout these 20 years. Despite improvements in the CPAP technology, dynamic breath-to-breath pressure titration, and including the use of Bi-level therapy, CPAP compliance has been at a dismal low level.

The authors demonstrate a clear shift of the sleep surgeons' preference towards more innovative anatomically targeted surgical procedures, instead of the old traditional non-selective UPPP. It demonstrates a change in philosophy in the thought process of sleep surgeons and that sleep surgeons are aware that sleep apnea surgery is reconstructive and not ablative surgery. The steady decrease of the UPPP technique, 2001–2010, from 25.6% (264 out of 1034) to 12.6% (213 out of 1681) in the following next 8 years, 2011–2018, is indicative of the paradigm shift.

There was a significant reduction in both AHI and ESS, the mean decrease in AHI (pre- to post-procedure) was from 35.66 to 13.91 ($p < 0.001$), while the mean decrease in ESS (pre- to post-procedure) was from 11.65 to 5.08 ($p < 0.001$).

The mean AHI change was 22.7 (SD 8.32, range of 4.9 to 36.9) ($p < 0.001$), with mean ESS change 5.8 (SD 2.2, range of 2 to 10) ($p < 0.001$) and mean success rate of 67.5%.

The meta-analysis of the respective palate procedures demonstrated that the surgical procedure that achieved the best AHI reduction was the anterior palatoplasty, with a mean reduction of 24.7 (range 20.79–28.6) ($p = 0.015$), followed by the lateral/expansion pharyngoplasty procedures at a reduction of 19.8 (range 16.90–22.64) ($p = 0.046$), and the least reduction was the classical UPPP, at 17.2 (range 12.68–21.83) ($p = 0.360$).

The authors acknowledge that there are some short-comings with the analysis, (a) although the data presented may be statistically significant, it may not be clinically significant, (b) the patients selected for anterior palatoplasty might have a less difficult anatomy, compared to those in whom a lateral/expansion procedure was done, (c) all these 59 articles are fairly heterogeneous, each article differs in their methodology, (d) these different articles report their data and results differently, (e) different authors have different surgical techniques to address the palate, (f) different nomenclature of palatal procedures will inevitably have some overlap in surgical steps, and, as with most medical literature, there is always a reporter bias (i.e. authors tend to and are more willing to report and publish good results).

The objective of this paper is not to illustrate nor demonstrate the different surgical techniques in the treatment of OSA, but rather to highlight the importance that (1) the efficacy of upper airway surgery has been steadily improving with better airway evaluation techniques, (2) there are innovative, logical yet simple surgical techniques that address the relevant anatomical site of obstruction, that work, and (3) sleep specialists need to continue to attend sleep courses to upgrade themselves and learn new diagnostic and therapeutic methods, in order for their patients to benefit with better success rates.

2.6 Conclusion

The authors highlight that (1) the surgical success rates of upper airway surgery has been steadily improving with the introduction of better airway evaluation techniques, (2) newer innovative surgical techniques can address the relevant anatomical site of obstruction, that work, and (3) there is an obvious shift towards the new generation of palate surgeries and away from the traditional ablative UPPP technique.

Acknowledgment There are no financial disclosures and no conflict of interest for all the above authors.

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3 Barbed Suture Technology

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3.1 Introduction

In the last 20 years, many new palatal surgical techniques for snoring and obstructive sleep apnea (OSA) were devised to address mainly the lateral pharyngeal wall and to enlarge laterally the oropharyngeal inlet [1–5].

Over the time surgeon experience, systematic retrospective review of literature, and targeted cadaver dissection study prompted to modify approach to lateral pharyngeal wall/retropalatal airway switching from lateral pharyngoplasties to the relocation pharyngoplasty according to Li [5], with several modifications suggested by experienced surgeons.

Among these modifications, barbed pharyngoplasty was certainly one of the most worthy of mention. The following principles were introduced:

1. "Barbed" which refers to the use of knotless bidirectional absorbable sutures introduced for similar purposes by Mantovani et al. [6].

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_3

2. "Repositioning pharyngoplasty" because it displaces the posterior pillar (palatopharyngeal muscle) in a more lateral and anterior position to enlarge the oropharyngeal inlet as well as the retropalatal space.
3. Suspension of the posterior pillar to the pterygomandibular raphe.

The multiple lateral sustaining suture loops of Barbed Reposition Pharyngoplasty (BRP) proved to be more stable than the single pulling tip suture of ESP, with no risk of tearing the muscle fibers losing the entire pulling force [7]. In addiction knotless surgical suture is much faster and easier, thus leading to a reduction of surgical time.

3.2 Technical Features

The barbed suture is a type of knotless surgical suture that has barbs on its surface. These barbs penetrate inside the tissue and lock it into place, eliminating the need for knots to tie the suture.

Barbed technology was initially used in cosmetic surgery [8], but along the years it has been introduced as an efficient, safe, and effective technology for various surgical procedures [9–11].

A broad range of barbed devices was designed to optimize surgical results and wound closure of different surgical tissues.

The portfolio of Barbed suture devices includes:

- three anchor technologies (unidirectional spiral, bidirectional spiral, and symmetric) for maximum versatility;
- a variety of lengths and sizes of wires and needles;
- different polymer's types (short-term, long-term, and non-absorbable polymers to suit multiple tissue types).

The versatility of barbed suture depends on complex design features that work together to strike the right balance between strength and smooth tissue passage.

The overall performance is due to:

- Barb geometry.
- Suture polymer.
- Barbing pattern.

The geometry of the individual barbs affects two kinds of strength of a barbed suture:

- Tensile strength: the suture's resistance to breaking under tension.
- Tissue-holding strength: the suture's ability to hold onto tissue under tension.

The principles that influence barb geometry and therefore strength are: cut depth, cut angle, and barb length.

Increasing cut depth improves the barb's tissue-holding strength but decreases the device's tensile strength because less core remains. Decreasing cut angle makes the barbs thinner and therefore more flexible, for potentially smoother tissue passage. Ultimately, barb length is a product of cut depth and angle.

The goal is to achieve the right equilibrium on cut angle and barb depth to optimize both barb geometry and core size for proper barbed system strength.

The polymer defines the short- and long-term strength as well as the intra-operative handling of the barbed suture, just as it does with traditional suture.

Different polymers present different breaking strength retention (BSR) and various absorption profiles, in order to be compatible with the specific properties of each type of tissue and adequate for the surgical interventions.

The barbing pattern also influences the overall suture system strength and depends on spirality and pitch.

– Spirality is defined as how tight the spiral pattern goes around the device, such as threads on a screw.
– Pitch is the spacing between barbs, represented by barbs per unit length.

Compared to traditional suture, barbed devices demonstrated superior tissue-holding strength, easier handling (especially in a narrow surgical field), and better management of tension over the tissue.

Today, the available barbed sutures in the market are:

– STRATAFIX by ETHICON.
– V-LOC by COVIDIEN.
– QUILL Knotless by BRAUN.
– LAYA KNOTLESS suture-closure device by BIOTEGY.
– DURABERB by DOLPHIN SUTURE.
– TRUBARB by HEALTHIUM.
– FILBLOC by ASSUT EUROPE.

Based on our experience at Morgagni Pierantoni Hospital of Forlì we believe that barbed suture technology is a reasonable option for palate surgery [12–14]. Compared to traditional suture it guarantees the right balance between strength, handling, and time of absorption.

The main devices used in our department are:

• STRATAFIX™ Spiral PDO 3-0 (Ethicon).
• V-Loc™ 180 3-0; needle V-20-1/2c—26 mm (Medtronic) (Figs. 3.1 and 3.2).

Both threads (uni- and bidirectional) are composed by a long-term absorbable polymers with spiral barbing pattern and present cutting circular needles (1/2c, length between 20–30 mm).

In our opinion, 3-0 size thread allows the right balance between tissue-holding strength and resistance to break.

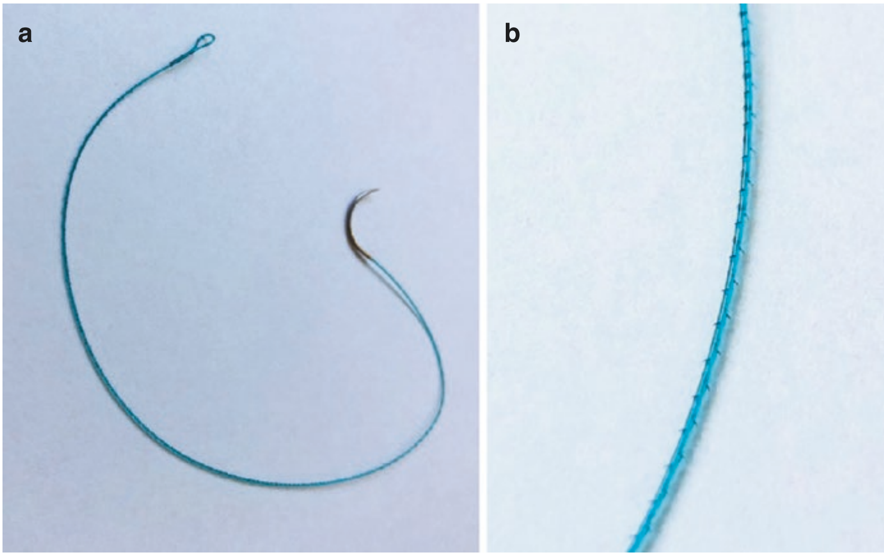
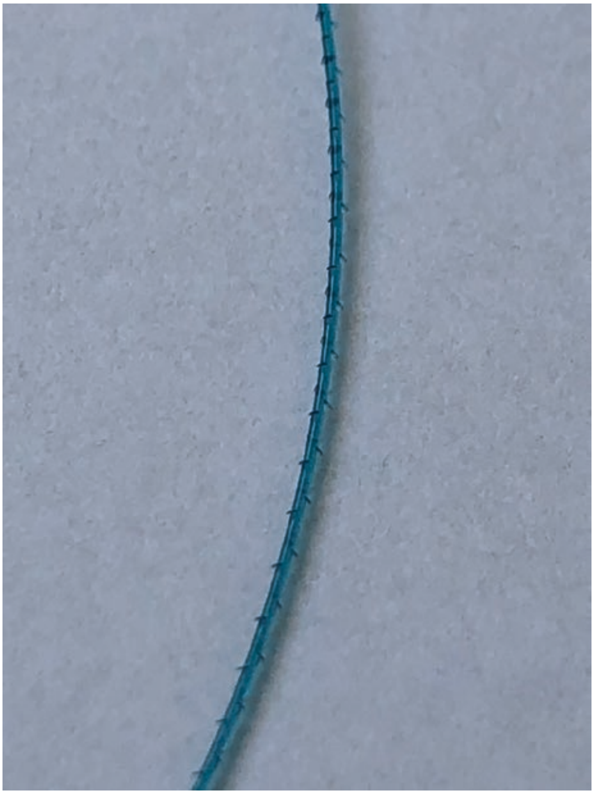


Fig. 3.1 V-Loc™ 180 3-0; needle V-20-1/2c—26 mm (Medtronic): (**a**) barbed wire, (**b**) detail on barbs

Fig. 3.2 Detail on barbs and thread



The peculiarity barb depth geometry gives more tissue-holding strength, whereas specific cut angle geometry preserves flexibility for potentially smoother tissue passage.

Moreover, the cutting circular needles penetrate tissue more easily and facilitate surgical steps.

3.3 Advantages of Barbed Suture Technology in Pharyngeal/Palatal Surgery

The main advantages are:

- the geometry pattern that allows to perform more thread loops around the muscle, creating a sort of dense net, for a better distribution of the repositioning forces over the muscle flap with less risk to tear the flap tip;
- the long-term absorption of the suture that guarantees a persistent traction on the muscle until the scarring process of fibrosis determines the stiffening of the relocated oropharyngeal wall;
- the handling of the barbed devices that facilitate all surgical steps in comparison with conventional suture, not needing surgical knots.

3.4 Complications

Different papers have shown good anatomical and functional results of the barbed pharyngoplasties [12–14]. However, different authors have reported the possibility of extrusion of the barbed suture used in this technique in a medium- or long-term period.

Extrusion and Exposure (E&E) of the suture are possible complications of barbed sutures surgeries.

Gulotta et al. evaluated the rates of extrusions in 488 patients [15]. The paper is focused on functional, anatomical outcomes and on subjective patients discomfort [15]. They observed Extrusion and Exposition in 18.4% of patients subjected to BRP but these events did not influence subjective and PSG outcomes.

Another rare but possible complication during BRP is the detachment of the needle from the wire. In such cases it is necessary to leave the suture already positioned and start a new suture from beginning.

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4 Overview of Barbed Suture in Non-ENT Surgery

R. Sgarzani, S. Pasquali, and F. Marongiu

4.1 Technological Development of Barbed Sutures in Different Surgical Fields

The history of barbed sutures involved many inventors over the years, from many surgical backgrounds: each inventor was looking at the new product from a different point of view, and interestingly barbed sutures seemed the answer to different needs. The development of a technology that avoids the need to tie knots in fact is not only the answer to the new needs in endoscopic and robotic surgery, but provides also multiple advantages to skin wound closure, tendon repair, and surgical and nonsurgical soft tissue lifting.

In 1964 Dr. John Alcamo [1], a general surgeon, was granted a US patent for unidirectional barbed sutures for wound closure; the drawback was that the suture was unidirectionally barbed and the surgeon had to "double back" to secure the closure. After few years Dr. Alan McKenzie [2], an orthopedic surgeon, designed a device with multiple barbs in both directions, postulating that it might provide better tendon repair. Even if now we know that his idea had an amazing potential, he said he abandoned the project because his sutures took too much time to construct, alongside the responsibilities of his orthopedic practice. It was in 1972 that an American inventor, Dr. Tanner [1], patented a device with barbs in two directions, but only located at the end of the shaft.

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_4

In 1994 Dr. Gregory Ruff, a plastic surgeon, starting from McKenzie's studies and efforts, patented a cannulated device for single-direction insertion of a barbed suture. At the beginning plastic surgeons were mainly interested in the application for facial lifting, Dr. Marlen Sulamanidze in 1997 invented a bidirectional barbed polypropylene thread for facial lifting and named it APTOS, that is the acronym of anti-ptosis thread. It was first patented in Russia, but then the idea that barbed sutures could reverse facial aging became popular all over the world. Dr. Henry Buncke designed bidirectional sutures, his patent described methods to manufacture the suture and a list of applications such as wounds closure, tendon repair, and face-lift. Dr. Woffles Wu, in 2001, increased the number of barbs in each direction and also designed the suture in a V-shaped pattern, instead of a slight arch; the V eliminated the tendency for migration and extrusion seen with APTOS. Dr. Nicanor Isse in 2003 used another approach, he thought to flip the suture around so that the barbs were pointed up. In this way the laxity was transferred to the temple area, where he anchored each unidirectional thread with knots.

In September 2004 FDA approved the first barbed suture licensed from Quill Medical, it was an unidirectional 2-0 polypropylene thread with a straight needle for midface suspension. In October 2004 FDA approved the use for wound closure of a bidirectional barbed suture licensed from Quill Medical with a curved needle on each end, made of absorbable polydioxanone.

After the FDA approval, contour threads were widely used by plastic surgeons in various minimally invasive percutaneous rejuvenation procedures to lift ptotic tissues, including brow, midface, and neck, but the popularity of the procedure did not last long because of the limited longevity of the results and because the result often did not reflect the patient expectations.

In the meantime since FDA approval barbed devices for wound closure have constantly increased their popularity and their applications in other surgical specialities [3].

Covidien V-LOC unidirectional absorbable barbed device was FDA approved for wound closure in 2009, its feature was a looped to anchor the suture line. Ethicon Stratafix was FDA approved in 2015.

4.2 Current Surgical Applications of Barbed Sutures in Laparoscopic and Robotic Surgery

Minimally invasive surgery such as laparoscopic surgery and robotic surgery has become more and more widespread over the last decades for the important advantages mainly in recovery time. Laparoscopic and robotic suturing with intracorporeal knot tying is a difficult surgical skill to acquire, in this environment barbed sutures offer several advantages, in fact the self-anchoring system avoids the need for knot tying and provides a rapid and consistent wound closure, with even distribution of tension across the wound. For these reasons barbed sutures are frequently used in all surgical specialities where laparoscopic and robotic surgery are becoming the standard of care, such as urology, gynecology, general surgery, and orthopedics.

In gynecology the use of barbed sutures facilitates the closure of the vaginal cuff during total laparoscopic hysterectomy; moreover, in laparoscopic myomectomies they allow safe and tension-free approximation of the myometrium. In gynecologic endoscopic surgery the use of barbed sutures is reported also with the use of an automated suturing device, with advantages to both the novice and the experienced surgeons [4].

In urology with the increase of robotic prostatectomies, the use of barbed suture is more and more important. The benefits of barbed sutures in performing robotic vesicourethral anastomosis have been studied and approved, in fact they allow a watertight seal and resistance to disruptive forces, reducing complication rate [5]. In urinary tract reconstruction, it has been tested that barbed sutures provide the same secure tissue approximation as standard tied sutures do, with decreased anastomotic time [6].

Furthermore the use of barbed sutures is often reported in laparoscopic surgery for bladder repair and suspension and for bowel surgery and enterotomies [7].

In general surgery the use of barbed sutures is reported in robotic bypass bariatric surgery to suture enterotomy and laparoscopic upper gastrointestinal surgery [8].

The use of barbed sutures in orthopedic arthroscopy has important advantages, including faster tying and no need to manipulate complex instruments. In tenorrhaphy barbed suture finds a special application, in fact the absence of knots allows the use of larger sutures, resulting in an increased tensile strength of the repaired tendon. In addition there is less distortion of the tendon's diameter and hence gliding should be facilitated [9].

4.3 Barbed Sutures in Wound Closure and Plastic Surgery

Barbed sutures can be easily used for skin wound closure in different settings. During product development extensive preclinical testing by Dr. Gregory Ruff and colleagues has ensured that the tensile strength of these materials provides sustained soft tissue approximation and the absorption curve is compatible with the time that is required to allow collagen deposition, ensuring the integrity of soft tissue approximation [1]. According to Hammond, closing a wound with a barbed suture gives to the final scar a subjective improvement [10], probably as a result of the near-complete stabilization of the wound edges; the barbed nature of the suture prevents tissue sliding and micro-motion and the final appearance of the scar is a thin and fine line, as is only occasionally seen with traditional methods of wound closure.

An important advantage of this technology for tissue approximation is the speed and ease of placement, with no need for an assistant's hand to follow the suture placement. In addition, deep stitches are often not required or only a few deep approximation stitches are necessary, and also this reduces the operative closure time. Rubin et al. [11] compared absorbable sutures to a unidirectional barbed suture for closure of open wounds in a multicenter randomized controlled trial. They noticed that the mean time to close the dermis was significantly faster in all the procedures where barbed sutures have been used.

Furthermore the attachment of the soft tissue to the barbs and the equal distribution of the tension along the incision line are effective in providing a strong resistance to wound separation. Other advantages are a reduced risk of knot slippage, knot breakage, suture extrusion or spitting, and lower risk of infection.

In the emergency room the possibility to close multiple wound layers with running barbed sutures can significantly decrease the time required for closure. Barbed sutures can be used in general and thoracic surgery to efficiently and securely close laparotomy and thoracotomy incisions.

There have been numerous applications in the plastic surgery literature, including facial cosmetic surgery, breast surgery, and body contouring. In facial rejuvenation surgery [12, 13] barbed sutures are currently used in open procedures to suspend deeper tissues, they can be applied more superficially (into the SMAS superficial musculo-aponeurotic system) or as deep as the periosteal plane. The most important applications for barbed sutures in facial esthetic plastic surgery are those involving lift of the brow, midface, lower face, and neck. To obtain an harmonious rejuvenation all these areas require surgical maneuvers to lift tissue volume with the right vector, there are 5 essential steps required in order to use barbed sutures: incisions, dissection of the desired plane, deployment of the threads, proximal anchoring, and molding soft tissues.

Barbed sutures are also useful in breast surgery. Mitchell et al. showed that for most breast procedures the net cost of using barbed sutures versus standard ones is essentially equivalent, so any savings in operating room time result in significant overall cost savings [13].

Also Salzberg has observed a decrease in his operative time in breast reconstruction with the use of barbed sutures [14]. In bilateral mastectomy he can close both sides simultaneously without assistance and he was able to control skin tension on closure by more uniform distribution of vectors along the skin edge. Barbed sutures can be used to inset acellular dermal matrix to the pectoral muscle and to define the pocket by recreation of the inframammary fold and lateral breast curvature [14, 15]. In implant based breast reconstruction barbed sutures can reduce the risk for deep infections by perfectly and steady juxtaposition of wound edges resulting in an "hermetic sealing" of the wound (Fig. 4.1a–c).

Barbed sutures are also used in autologous reconstruction to repair the rectus abdominal fascia, to inset synthetic mesh or ADM, to inset the flap at the recipient site, or for layered closure of the flap donor site, such as the lower abdomen or the dorsum.

A double ended barbed unidirectional suture (Quill suture) can be also used to position and manipulate the breast mound during reconstructive and esthetic breast surgery [16], once the surgeon is satisfied with the breast footprint and volume, the breast mound is moved to the desired location.

In cosmetic breast surgery the main advantage is the capability to adjust as desired the amount of tension with each bite, as well as to better and easily re-drape skin excess allowing greater control of the final scar appearance (Fig. 4.2a–c).

With the increase of bariatric procedures, there has been a similar increment in the number of body contouring procedures. The main characteristics of barbed sutures, such as the lack of necessity to tie knots, distribution of wound tension and faster wound closure, make barbed sutures well suited for body contouring procedures such as standard and circumferential abdominoplasties and bodylifting. Many

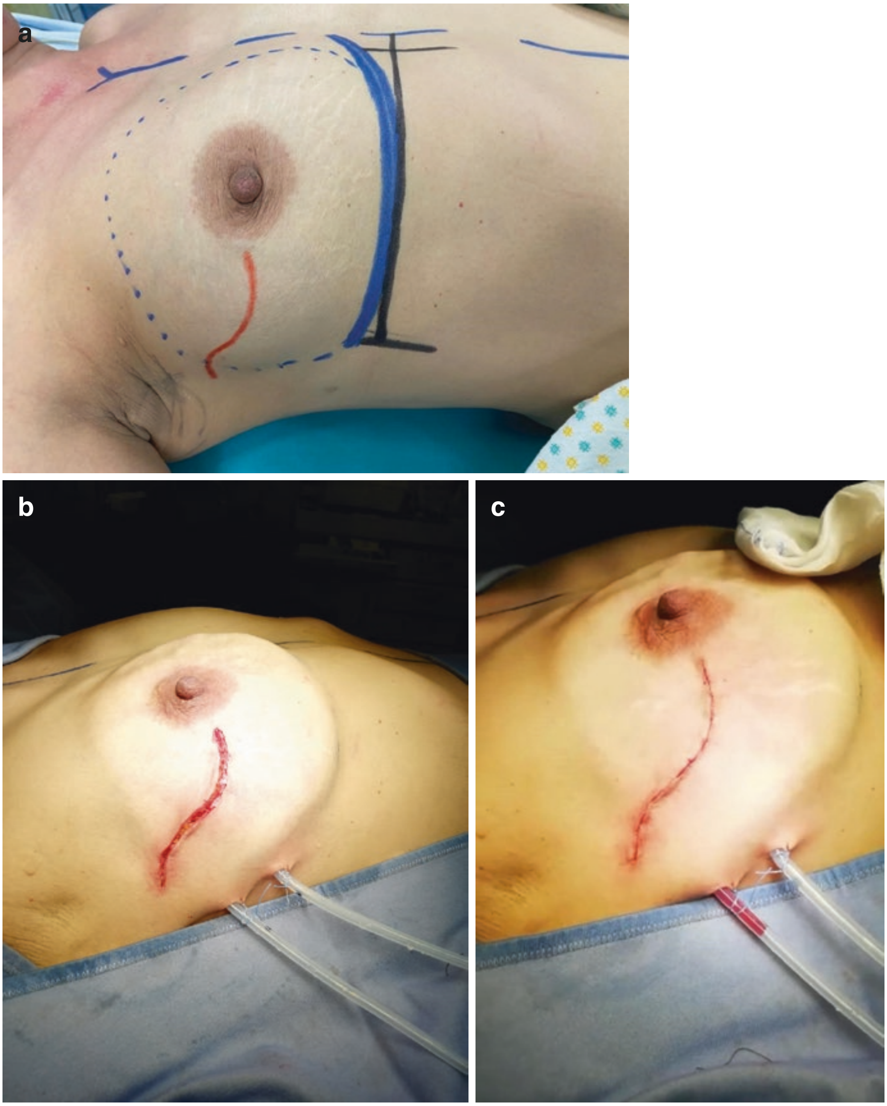

Fig. 4.1 (**a**) Pre-operative picture of a 43-year-old patient affected by right breast cancer, with indication to nipple-sparing mastectomy through a "lazy-S" incision followed by an acellular dermal matrix ADM-assisted prepectoral direct to implant breast reconstruction. (**b**) Intra-operative picture, once the reconstruction was completed we performed a simple deep suture layer with few deep resorbable 4/0 braided suture to juxtapose the skin edges. (**c**) Intra-operative picture, continuous superficial layer of 4/0 monodirectional resorbable barbed suture to reduce the wound tension over the more superficial layers and ensure a "hermetic sealing" of the wound

authors, including Moya [17], described an important reduction of time using barbed suture in abdominoplasty in spite of conventional sutures. In abdominoplasty procedures barbed sutures can also be successfully used for fascial plication to correct diastasis recti. One of the biggest advantages Moya described was the

Fig. 4.2 (**a**) Pre-operative picture of a 36-year-old patient undergoing bilateral Wise-pattern augmentation mastopexy (Mentor CPG 322–255 cc). (**b**) Wise-pattern closure was performed with 3/0 resorbable braided suture at the inverted T junction and at the cranial edge of the vertical suture line, followed by a continuous superficial layer of 4/0 monodirectional resorbable barbed suture. The intra-operative picture shows the perfect wound edge match that was achieved as well as the optimal skin-redraping with no sign of dog-ear deformity at wound edges. (**c**) 3 months post-operative picture. The wounds healed perfectly, with no sign of wound break-down, no inflammation, and no excess of skin at wound edges

elimination of hand fatigue, usually due to the many knots required for a 2-layer plication of the abdominal wall with large-gauge monofilament (Fig. 4.3a–c). Also, the improved appearance of the scar makes this an attractive option for these patients, for whom the scar burden can be extensive [18].

Fig. 4.3 (**a**) Pre-operative picture of a 51-year-old patient with skin laxity and excess over the lower abdominal quadrants, candidate to abdominoplasty with rectus muscle plication and umbilical repositioning. (**b**) We performed a deep layer of 2/0 resorbable braided suture for the Scarpa's fascia, followed by another deep layer of 3/0 resorbable braided suture and a continuous superficial layer of 4/0 monodirectional resorbable barbed suture. The intra-operative picture shows the perfect wound edge match that was achieved as well as the optimal skin-redraping with no sign of dog-ear deformity at wound edges. (**c**) First post-operative day picture. Barbed sutures allow to adjust as desired the amount of tension with each bite, as well as to better and easily re-drape skin excess (dog-ear) allowing greater control of the final scar appearance

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5 Overview of Different Barbed Procedures for Sleep Breathing Disorders

Claudio Vicini and Fabrizio Salamanca

Mantovani et al. [1] in 2012 described the first application of a barbed suture to the palate surgery for patients with snoring. In 2014 Salamanca et al. [2] introduced barbed technology into a modified anterior palatoplasty as obstructive sleep apnea treatment.

Vicini et al. [3] in 2015 described an original type of pharyngoplasty using barbed suture for repositioning released muscles in a more favorable location for preventing vibration and collapse.

In 2018 Sorrenti et al. [4] introduced the Functional Expansion Pharyngoplasty based on unidirectional barbed sutures.

Table 5.1 summarized, according to the year of publication, these four palate techniques to treat velo-pharyngeal collapse of patients with snoring and sleep apnea. We are particularly proud that all the four contributions arise from different Italian centers.

Barbed surgical techniques discussed in this book have different features according to:

(a) The direction of the pulling vector produced by the barbed suture array.
(b) The use of bi-directional barbed vs. mono-directional.

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_5

Table 5.1 Different barbed procedures for sleep disordered breathing

Published paper	Mantovani et al. (2012) [1]	Salamanca et al. (2014) [2]	Vicini et al. (2015) [3]	Sorrenti et al. (2018) [4]
Main pulling vector	External	Anterior	External	Anterior
Type of barbed suture	Bi-directional suture	Bi-directional suture	Bi-directional suture	Mono-directional suture
Sub- vs. extra-mucosal technique	Submucosal techniques	Submucosal techniques	Submucosal techniques	Extra-mucosal techniques
Palatopharyngeal muscle release	NO	NO	YES	NO
Palatopharyngeal muscle flap	NO	NO	NO	YES
Supra-tonsil fat dissection	NO	NO	YES	NO
Uvula management	NO	NO	Trimmed	NO
Midline crossing sutures	NO	NO	YES	NO

(c) The use of a completely submucosal suture vs. a trans-mucosal suture, with partial exposure of the thread.
(d) The possible palatopharyngeal muscle manipulation (release or flap raising).

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6 Qualitative Phenotyping by Surrogate Index for the Selection of Patient Candidates for Velo-Pharyngeal Surgery

Marcello Bosi and Andrea De Vito

Obstructive sleep apnoea (OSA) is a heterogeneous disorder in terms of its pathogenesis and clinical expression, and its severity rating cannot be further limited to the AHI score, the most widely used parameter for diagnosis and description of severity until today. It is increasingly recognized that patients with similar AHIs scores may have vastly different endotypes (functional and pathophysiological mechanisms of OSA) and different phenotypes (symptoms, response to therapy, quality of life, prognosis—especially in terms of cardiometabolic disease and mortality, health outcomes). The idea of grouping patients with OSA according to phenotypes or according to endotypes is gaining ground in literature. The classification of OSA according to phenotypes and defining the observable consequences of a disease as a phenotype does not describe pathogenetic mechanisms. An endotype is a specific functional or pathobiological mechanism of OSA, and several physiological endotypes have been identified as playing a likely causal role. To develop OSA, all patients must have some degree of anatomical compromise (anatomical collapse) but in addition to this anatomical predisposition, at least three non-anatomical endotypes also play a key causal role in many patients with OSA [1]. These non-anatomical endotypes include neuromuscular effectiveness/responsiveness to the collapse, the respiratory arousal threshold (AT), and the ventilatory control system (Loop Gain, LG).

Anatomical Collapsibility What contributes to anatomical collapse is a heterogeneous combination of many factors, such as obesity, craniofacial structure, lung volumes, fluid shifts, nasal resistance, or upper airway surface tension [2].

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_6

An increase in pharyngeal anatomical collapsibility could occur in the presence of quantitatively normal soft tissues, hyperplastic soft tissues (e.g. adenotonsillar hypertrophy, tongue base hypertrophy), or maxillofacial anatomical abnormality (e.g. micro-retrognatia, maxillofacial malformation syndromes), and consequently a pathological narrowing of upper airways.

Other conditions causing or worsening the anatomical collapse of the pharynx are:

- Excessive shifting of fluids from the lower limbs to the neck when the patient is in a supine position;
- All pathological conditions that cause reduced lung volumes (e.g. pulmonary fibrosis, neuromyopathies with respiratory evolution, fibrothorax). The lung and the lower airways are anatomically connected to the upper airways and the stability of the pharynx also depends on this anatomical connection (lower tracheal traction); reduced lung volumes destabilize the pharynx, increased lung volumes stabilize it. In thoraco-pulmonary diseases with reduced lung volume, there is a reduction of lower tracheal traction and consequently the pharynx is more collapsible.
- Abdominal fat pressure on the thorax in supine position always causes a lung volume reduction.

The gold standard for measuring anatomic pharyngeal collapsibility is passive pharyngeal critical pressure (passive P_{crit}), the value of pharyngeal pressure at which complete pharyngeal collapse occurs during fast and short CPAP reductions of therapeutic value in non-rapid eye movement (NREM) sleep and supine position [3].

In relation to the value of passive P_{crit}, there are 4 levels of pharyngeal collapse:

- high (P_{crit}> +2.5 cmH_2O),
- intermediate (P_{crit} between −2.5 and +2.5 cmH_2O),
- low (P_{crit} between −2.5 and −5.0 cmH_2O).

More recently other parameters have been introduced to describe the anatomical propensity of pharyngeal collapse, V0- passive, for example, which describes flow expressed as an absolute value or as a percentage of eupneic ventilation developed when CPAP value is quickly reduced from therapeutic to 0 cmH_2O [4].

Neuromuscular Compensation This is the ability to recruit the pharyngeal muscles as a result of blood gas level changes (O_2 and CO_2) and negative pharyngeal pressure swings caused by the obstructive event and has the purpose of compensating the obstruction from passive collapse, as much as possible. Active P_{crit} is the gold standard measurement for the neuromuscular compensation of an obstructive event, i.e. the pharyngeal pressure value at which complete pharyngeal collapse occurs during slow CPAP reductions from therapeutic value, during NREM sleep and supine position [3]. Other parameters for neuromuscular compensation include electromyographyc pharyngeal muscle responsiveness to negative pharyngeal pressure swings. In contrast, V0 –active describes the flow, expressed as an absolute value or as a percentage of eupnoic ventilation, developed when CPAP is reduced from minimum tolerable value avoiding arousal to 0 cmH_2O. In the $\dot{V}0$- passive procedure, the pharyngeal muscles are hypotonic or relatively passive; in the $\dot{V}0$-active procedure the pharyngeal muscles are more active and stiffening the upper airway [4].

Ventilator Control-Loop Gain Ventilatory control contributes to the homeostasis of blood gases. It depends upon the stage and state of sleep and is characterized by supra-pontine and metabolic control during rapid eye movement (REM) sleep stage and by predominantly metabolic control during NREM sleep stage. The LG, an engineering model of ventilator control, has been adopted to simplify the complexity of metabolic ventilatory control during NREM sleep. It consists of a control component (chemoreceptors and ventilator centres: controller gain), an exchange component (lung: plant gain), and a connection component (circulation and tissue diffusion: circulatory time).

Figure 6.1 describes the LG model:

- The control element of blood gases (controller) represented by the central and peripheral chemoreceptors and their afferents via the vagus and glosso-pharyngeal nerve to the brainstem respiratory centres, the efferences of the latter to the intercostal respiratory muscles and to the diaphragm through the phrenic nerve and intercostal nerves, respiratory muscles.
- The gas exchanger element (plant) represented by the lung.
- The connecting element between controller and plant, consisting of circulation and gases tissue diffusion.

A high LG can lead to excessive ventilatory responses and the destabilization of ventilation during sleep, resulting in periodic breathing and facilitating sub-obstructive and obstructive upper airway events. Initially, LG was measured using mechanical ventilators or continuous pressure devices: LG is the ratio of the ventilatory overshoot (response) above V-eupnea when returning to optimal CPAP pressure from a period of sub-optimal CPAP with reduced ventilation (disturbance) [4].

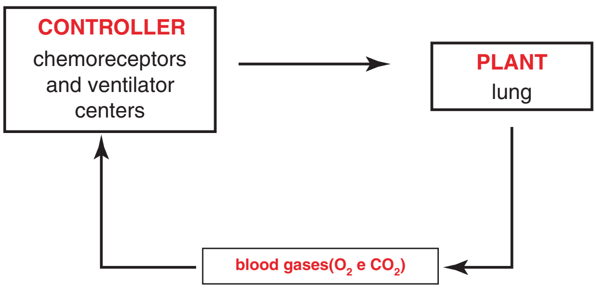

Fig. 6.1 LOOP GAIN (ventilation control). Organized to maintain the homeostasis of blood gases (O_2 and CO_2) when hyper-responsive it is the cause or contributing cause of OSA

More recently, LG has been measured by easier methods, such as the application of clinical polysomnography (PSG) analysis software [5].

Arousal Threshold The mechanical chemical imbalance caused by the obstructive event stimulates an electroencephalographic awakening, which breaks off the obstructive event of the upper airways by stimulating an increased response of the pharyngeal muscles [2, 6, 7].

The AT, the level of inspiratory effort measured by oesophageal or epiglottic pressure capable of evoking an arousal, is an invasive measure. Today, AT can also be calculated more easily and noninvasively by clinical PSG analysis software. It has been shown that hyper-responsive AT (present in 30–50% of all patients) can cause or lead to the onset and/or prolonged occurrence of obstructive events affecting the upper airways over time.

Arousals from sleep have been traditionally considered unavoidable and necessary in order to end an obstructive event. However, in more than 25% of obstructive events, arousals may not be observed at their end [2, 6, 7].

Figure 6.2 shows the role played in OSA by the 4 endotypes. If a high anatomical collapse can cause OSA regardless of the other 3 endotypic traits (inevitable OSA), low muscle recovery capacity (low UAG), high responsiveness of the arousal centre (low AT) and high responsiveness of the ventilation control mechanism (high LG), singly or in combination, can determine the appearance of OSA in patients in whom anatomic collapse is mild [8–10]. Therefore, the importance of non-anatomical traits is predicated by underlying anatomy. Prior studies have shown that in approximately one-third of people with OSA, non-anatomical traits are important for OSA pathogenesis and conversely, that such patients might benefit or be treated without the use of CPAP therapy. Furthermore, these anatomical and non-anatomical "endotypes" can be very different for patients categorized as having comparable OSA severity when assessed by the AHI, explaining why CPAP-alternative interventions such as oral appliances, upper airway surgery, pharmacological interventions (i.e.

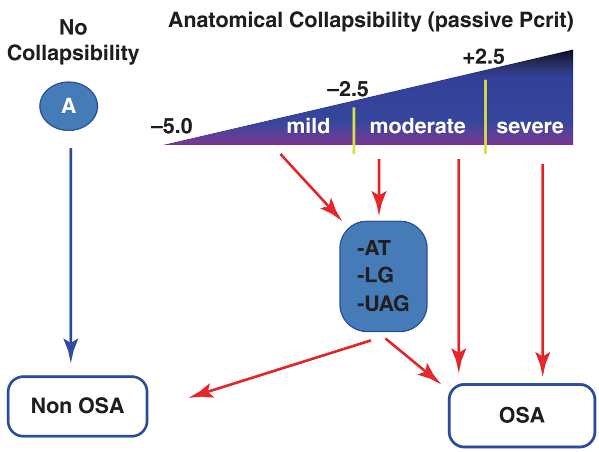

Fig. 6.2 Mutual interaction between endotypic traits

supplemental oxygen or sedatives) have to date shown only a modest improvement in OSA severity when administered to unselected patients.

The therapeutic efficacy of a non-CPAP therapy essentially depends on 3 factors: [11, 12]:

- the patient's starting anatomical collapsibility (passive P_{crit}), which may be so severe that it cannot be recovered,
- the extent of reduced collapsibility with adopted therapy (measured as recovery of cmH_2O of P_{crit}),
- the degree of alteration of the other PTs when the procedure does not bring the patient to a P_{crit} value lower than -5 cmH_2O.

Patients with mild anatomical collapse can be corrected (i.e. brought to a P_{crit} value <-5 cmH_2O) even by therapeutic procedures that produce modest recoveries in Pcrit (Fig. 6.3a).

Conversely, patients with high collapse can only be corrected by procedures that enable the recovery of more than 8–9 cmH_2O (Fig. 6.3b) [11, 12].

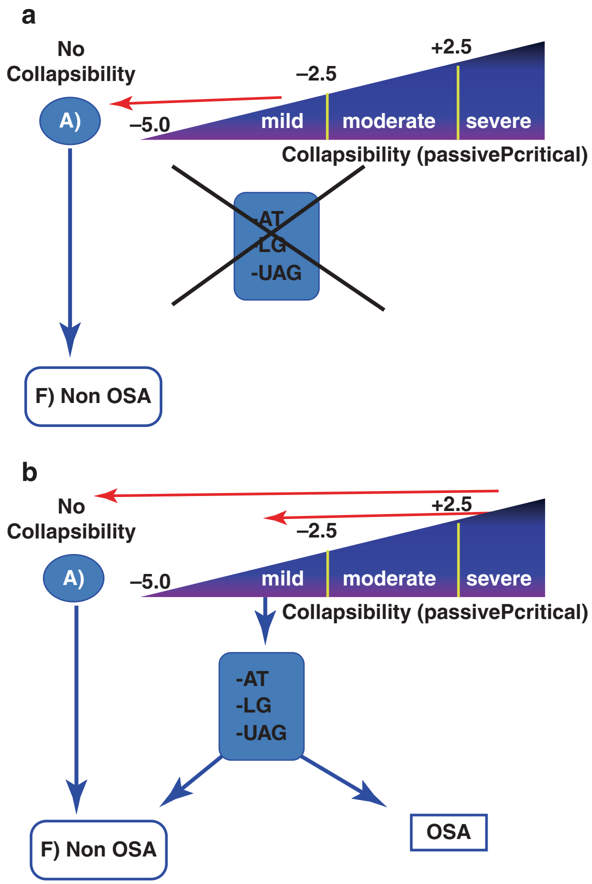

Fig. 6.3 (**a**) With low collapsibility it is sufficient to recover only 2.5 cm of P_{crit}. (**b**) With high collapsibility it is necessary to recover at least 9 cm of P_{crit}

6.1 Endotypic Traits and UA Surgery

Recent detailed physiological studies in relatively small numbers of patients have highlighted that knowledge of a patient's endotype is crucial for understanding which patients are most likely to show OSA resolution with non-CPAP interventions. Key highlights of this collective body of studies indicate that:

- OSA patients with a favourable anatomy (i.e. less pharyngeal collapsibility) and a low LG may have a great benefit from oral appliance therapy [13] and upper airway surgery [14].
- OSA patients who respond to supplemental oxygen have a high LG [8, 15, 16].
- OSA patients with poor muscle compensation at baseline experienced greater benefit from pharmacological therapies stimulating the upper airway muscles [17].

Upper airway surgery is often recommended for OSA patients, who refuse or cannot tolerate CPAP. Reduced anatomical collapsibility achievable by upper airway surgery is mainly the consequence of the expansion, stabilization, and/or ablation of upper airway pharyngeal obstructions.

Velo-pharyngeal surgery can modify functional as well as anatomical endotypes, while the clinical identification of unfavourable non-anatomical endotypic traits might predict response to surgery.

6.1.1 Upper Airway Surgery for OSA Modifies Anatomical Pharyngeal Collapsibility

Some studies are currently available on the relationship between upper airway surgery and pharyngeal collapsibility, demonstrating that the major impact of upper airway surgery is on the modification of passive collapsibility.

Schwartz et al. [18] showed a significant decrease in passive P_{crit} (from 0.2 ± 2.4 to −3.1 ± 5.4 cmH_2O, $P = 0.016$) after uvulopalatopharyngoplasty (UP3) but a significant fall in P_{crit} (from −0.8 ± 3.0 to −7.3 ± −4.9 cmH_2O) was found in responders only, whereas no significant change was detected in non-responders (from 1.1 ± 1.6 to 0.6 ± 2.0 cmH_2O, $P = 0.01$).

Woodson [19–21] compared transpalatal advancement pharyngoplasty with UP3 and found an increased maximal retropalatal airway size and a decreased passive P_{crit} (up to or over 9 cmH_2O).

Overall, these studies confirm that the primary mechanism of action of UA surgery for OSA is the modification of anatomical pharyngeal collapse and the level of recovery on P_{crit} (up to or over 9 cmH_2O) accounts for the significant success rate of UA surgery for OSA, even in well selected patients with severe pharyngeal anatomical collapsibility.

6.1.2 Clinical Endotypic Trait Analysis Could Predict UA Surgical Outcomes

It has been frequently speculated that variability in the response to surgery can also be ascribed to the fact that it does not improve LG and AT, which are often unfavourable in non-responders. To date, some studies have verified whether surgical procedures are capable of modifying extrapharyngeal endotypic traits as well and their role as possible predictors of surgical success [22, 23].

Li et al. [22] compared 15 control subjects with 30 OSA patients who underwent UA surgery, including horizontal-UP3 (H-UP3) alone (a conservative UP3 modified technique) for 13 patients, H-UP3 with concomitant transpalatal advancement pharyngoplasty for 15 patients, velo-pharyngeal and retroglossal surgery (H-UP3 and concomitant genioglossus (GG) advancement or hyoid suspension) for 2 patients. UA surgery improved AHI (−69.7% from basal). 15/30 of patients with OSA were responders (≥50% reduction in AHI and post-surgery AHI < 20 events/h), 8/30 (26.7%) were cured (post-surgery AHI < 10 events/h without residual symptoms), LG decreased by 24.2% from 0.70 (0.58–0.80) pre-operatively to 0.53 (0.46–0.63) post-operatively ($P < 0.001$), while no statistically significant change in LG occurred in a control group. A positive association was also observed between decreased LG and improved AHI ($P = 0.025$). The authors concluded that LG was reduced by UA surgical treatment and this reduction suggests that high LG may be acquired, at least partially. Therefore, reducing the severity of OSA and preventing exposure to intermittent hypoxemia may improve maladaptive chemoreflex control abnormalities, consequently lowering LG.

An interesting study [23] analysed the effect of UA surgery on extrapharyngeal endotypic traits and the use of LG and AT values in predicting surgical success rate (defined as AHI 50% reduction and a post-operative AHI <10 event/h). Forty-six patients with OSA underwent UA surgery. 39/46 patients underwent multilevel UA surgery (20/46 with tongue surgery, 4/46 only tonsillectomy, 3/46 nasal surgery only). Surgery decreased AHI (−39.1%) but surprisingly did not modify LG in the whole group as well as in the 2 subgroups of responders and non-responders (26% of the patients were responders). AT decreased both in the whole group and in the subgroup of responders; increased AT is linked to the severity of OSA due to sleep fragmentation, repetitive hypoxemia, damage of upper airway mechanoreceptors by noise and vibrations, brain habituation to increased levels of inspiratory effort [65]. Surgical responders had a lower baseline LG, according to logistic regression showing that a lower LG was a significant predictor of surgical success.

Li et al. [12] found that a physiology-based predictive model, including polysomnographic indexes related to the 4 endotypes, explained 61% of the variance in post-operative AHI and was able to predict post-surgical AHI (veil surgery and pharyngoplasty) with good accuracy.

A retrospective analysis of 46 polysomnograms before and after upper airway surgery found that LG measured noninvasively by clinical PSG can be different in relation to hypopnoea scoring criteria and this impacts the ability of LG to predict surgical success [24].

6.2 Techniques to Measure OSA Endotypes

Although these findings show promising and potential developments, the most important limitation of these approaches is that they require difficult and time-consuming protocols and definitely these procedures are not clinically practical or available. To successfully translate personalized OSA endotypic treatments to clinical practice, the field requires simple, clinically deployable endotyping methods that reliably identify patients most likely to accept, use, and benefit from non-CPAP treatments.

Most of the evidence demonstrating that OSA endotypes predict response to non-CPAP interventions comes from specialized physiology laboratories that have the sophisticated equipment and highly trained personnel required to measure these factors. The current "gold standard" methods to quantify all four endotypes simultaneously require complex manipulations of CPAP and/or require patients to sleep while heavily instrumented (e.g. pressure catheters in the upper airway/oesophagus, and EMG wires into key pharyngeal muscles) [1, 4, 25]. Not surprisingly, the clinical applicability of these methodologies is limited by their highly specialized and relatively invasive nature. For OSA endotyping to be clinically useful, it will require techniques that allow for the easy and noninvasive determination of endotypes. From a clinical point of view, to date, the production of easy and reliable tools for a semi-quantitative evaluation of individual traits from clinical PSG is now under way [26–30]. These are not measures but qualitative or semi-quantitative estimates only. Such estimates are commonly referred to as surrogates for endotype evaluation and they use the information contained within a routine clinical PSG, CPAP titration or require an additional test, which is performed during wakefulness or sleep.

Table 6.1 shows endotypic measure surrogates that are now easier to acquire and can be widely used in clinical practice.

Table 6.1 Simple clinically applicable endotyping tools

Endotype	Surrogate tool	Study	Performed in wake/sleep?	Additional test required?
Anatomical trait/site of collapse	Therapeutic CPAP level	Landry et al. [26]	Sleep	Yes/no
	Anthropometric and standard polysomnographic indices	Genta et al. [27]	Sleep	No
	CPAP manipulation during standard laboratory titration	Osman et al. [28]	Sleep	No
Arousal threshold	Standard PSG parameters	Edwards et al. [29]	Sleep	No
Loop gain	Breath-hold duration	Messineo et al. [30]	Wake	Yes (executable during the clinical visit)

6.3 Endotype Surrogate Measures for Clinical Application

Studies in literature on the clinical use of endotype surrogate measures are currently very limited in number. Findings suggest that surrogate measures of OSA endotypes help predict responses to both CPAP and non-CPAP therapies.

A patient's therapeutic CPAP level requirement, as a measure of an individual's degree of anatomical compromise [26], predicts whether they are likely to respond to the combination of oxygen and sedative as well as passive P_{crit}, which is usually only measured in the research setting [31]. Furthermore, using the method proposed by Edwards et al. [29], Zinchuk et al. [32], Hao Wu et al. [33] demonstrated that a low AT surrogate predicts poor long-term CPAP adherence, highlighting the importance of understanding a patient's physiological endotype, not only for treatment but also more broadly for the management of OSA. A low LG may identify populations at risk for low CPAP adherence and consequently identify a potential target for improving CPAP adherence modifying the arousal threshold pharmacologically [34–37].

6.4 Conclusions

Literature data on the relationship between endotypes and pharyngeal surgery are still limited to a small number of surgical procedures: UP3, H-UP3 with isolated anterior transpalatal pharyngoplasty or with associated tongue surgery. On the basis of these data, the following concepts emerge:

- Upper airway surgical treatment for OSA mainly, but not exclusively, modifies pharyngeal collapsibility;
- Upper airway surgical treatment for OSA could achieve P_{crit} improvement up to or over 9 cmH_2O;
- Functional endotypic traits (in particular the LG) are predictive factors for surgical outcome.

A future definition of the possible role of genotypes is desirable, also for velopharyngeal surgical techniques which are very common today, such as expansion sphincter pharyngoplasty (ESP) and barbed reposition pharyngoplasty (BRP).

In the clinical setting, the transition to a precision-based approach for the surgical treatment of OSA cannot ignore the integration of endotypic traits with endoscopic and clinical data in the pre-surgical global assessment of patients with OSA.

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7 Barbed Surgery Related Anatomy

Federico Leone, Fabrizio Salamanca, and Vittorio Rinaldi

7.1 Introduction

According to standard anatomic definitions, the pharyngeal airway is anatomically divided into three regions (Fig. 7.1): the nasopharynx, defined as the area behind the nose and above the soft palate; the oropharynx, from the soft palate to the upper border of the epiglottis; and the laryngopharynx, from the upper border of the epiglottis to the inferior border of the cricoid cartilage. Accurate evaluation of airways dynamic obstruction behind the soft palate and tongue led to subdividing the oropharynx into the retropalatal pharynx (or velopharynx) and the retroglossal pharynx, respectively [1, 2].

The adult human is the only mammal that suffers from Obstructive Sleep Apnoea (OSA), due to the lack of support of the oropharyngeal complex; in other mammals, the tip of the uvula touches the top of the epiglottis and the hyoid bone supports this segment by its articulation with the cervical spine. Concerning gender differences, some studies suggest that male predisposition to pharyngeal collapse is anatomically based, primarily as a result of the increased length of the airway—which makes it more vulnerable—as well as increased soft palate size [1].

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_7

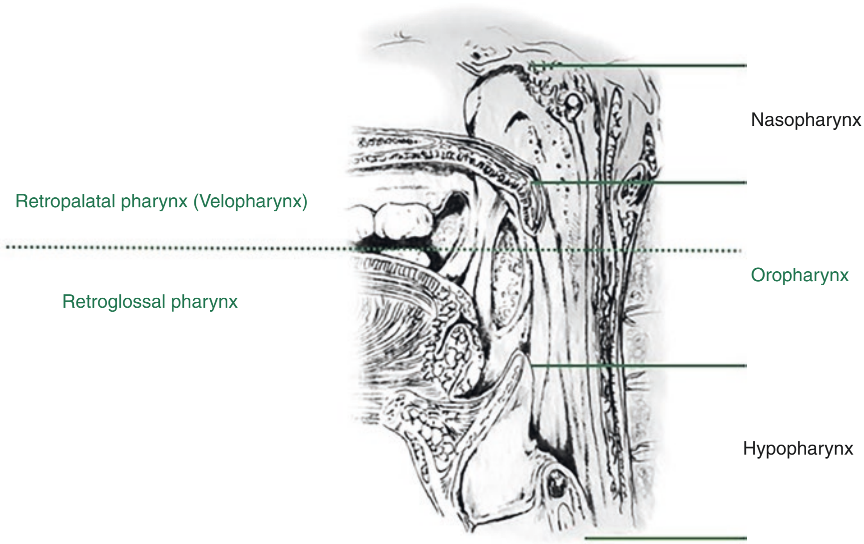

Fig. 7.1 Lateral view of pharynx

In this chapter, we discuss the anatomy of the oropharyngeal subsites and muscles and focus on the soft palate (velopharynx) that is our surgical target.

7.2 Oropharynx

The oropharynx extends from the lower surface of the soft palate to the level of the hyoid bone and is bounded laterally by the palatoglossal and palatopharyngeal arches (Fig. 7.1). The pharyngoepiglottic folds are considered parts of the laryngopharynx, and the epiglottis is part of the larynx. A subdivision in collapsible segments allows to refer the area posterior to the soft palate as the *retropalatal* pharynx, while inferior to that and posterior to the tongue (from the tip of the uvula to the tip of the epiglottis,) it is referred to as the *retroglossal* pharynx.

Muscular and non-muscular structures of the pharynx will be discussed in detail in the next paragraphs.

7.2.1 Soft Palate

The soft palate is a complex fibromuscular structure connected anteriorly to the hard palate by a tensor aponeurosis of connective tissue, which extends posterior-inferiorly from the margin of the hard palate. The palatine aponeurosis serves as attachment for most of the soft palate musculature and is continuous with the lateral pharyngo-basilar fascia and tensor veli palatini muscle tendons. The soft palate contains five muscles that are four paired slings and one midline muscle (Fig. 7.2):

- tensor veli palatini (TVP),
- levator veli palatini (LVP),
- palatopharyngeus muscle (PPM),
- palatoglossus muscle (PGM),
- muscularis uvulae (MU).

Palatal aponeurosis is continuous with the tendon of *tensor veli palatine* (Figs. 7.2 and 7.3). The TVP tendon exits the soft palate laterally and winds around the pterygoid hamulus to which it is partially attached, before ascending to its origin in the scaphoid fossa, to the spine of the sphenoid bone and membranous portion of the

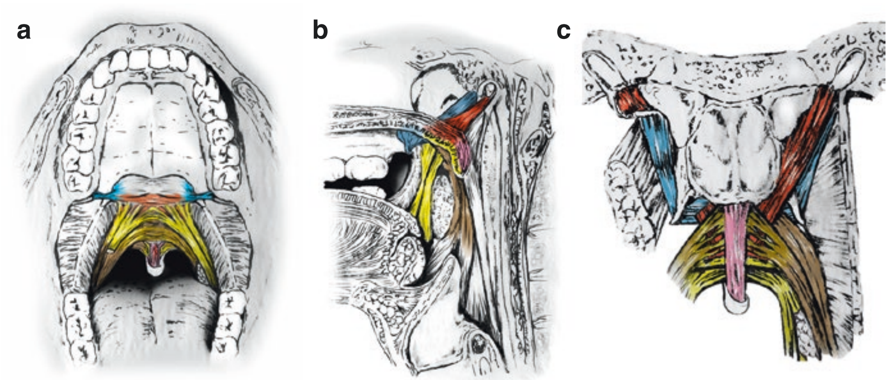

Fig. 7.2 Anterior (**a**), Lateral (**b**), and Posterior (**c**) views of muscles of the soft palate. Tensor veli palatini (*blue*), levator veli palatini (*red*), palatopharyngeus (*brown*), palatoglossus (*yellow*), muscularis uvulae (*pink*)

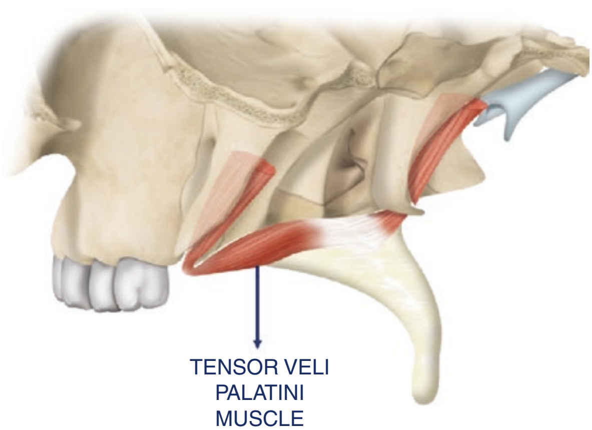

Fig. 7.3 Tensor veli palatini muscle (posterolateral view)

tympanic tube. The primary function of the TVP is to tend the soft palate, thus assisting the levator veli palatini (that elevates the palate) in sealing the nasopharynx. Another function of the TVP is to help maintain patency of the Eustachian tube.

The *levator veli palatini* (LVP) muscle originates on the inferior surface of the petrous temporal bone and from the infero-medial aspect of the Eustachian tube cartilage; it travels infero-anteriorly and medially, eventually between the muscularis uvula and palatopharyngeus, and inserts into the soft palate (Figs. 7.2, 7.3, 7.4). It contributes to soft palate bulk, opens the Eustachian tube, and pulls the soft palate backwards to reach the posterior pharyngeal wall.

The *palatopharyngeus muscle* (PPM) (posterior pharyngeal pillar) is the most superficial and posterior of soft palate muscles. It originates from the hard palate and palatine aponeurosis and inserts into the lateral pharyngeal wall, to the thyroid cartilage and pharyngeal aponeurosis. Its anterior and posterior extensions blend into the muscularis uvulae and levator veli palatini (Figs. 7.2, 7.3, 7.4, 7.5). Within the velum, it is split into two heads by the insertion of the LVP. Running downwards and laterally from the velum, it forms the posterior pillar of fauces. During swallowing, PPM tends the soft palate and pulls the pharyngeal walls upwards, anteriorly, and medially. Altogether, the LVP and PPM work along with the superior constrictor to close the retropalatal pharynx: an event that is fundamental in speech and swallowing.

The *palatoglossus muscle* (PGM) (anterior pharyngeal pillar) originates from the palatine aponeurosis and inserts laterally to the tongue. It draws the posterior tongue and soft palate together (Fig. 7.2).

The *muscularis uvulae* (MU) (Figs. 7.2, 7.3, 7.4, 7.5, 7.6) lies just posteriorly to the PPM. It extends inferiorly in the soft palate midline and pulls the uvula superiorly and anteriorly. The function of the MU remains unknown [3].

Motor innervation to the soft palate is conveyed by branches of the ascending pharyngeal plexus (X), except for the TVP that is innervated by a branch of the mandibular nerve (V3). Blood supply to the palate comes from the greater

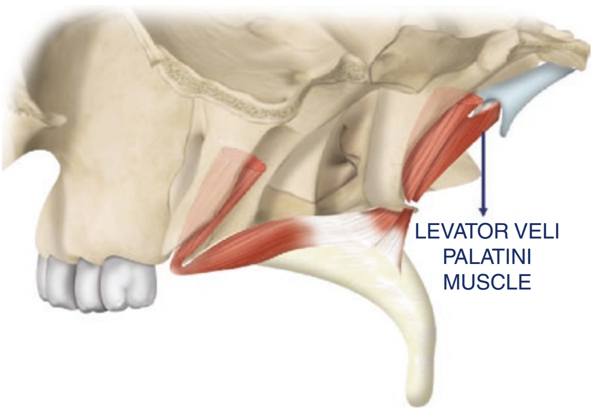

Fig. 7.4 Levator veli palatini muscle (postero-lateral view)

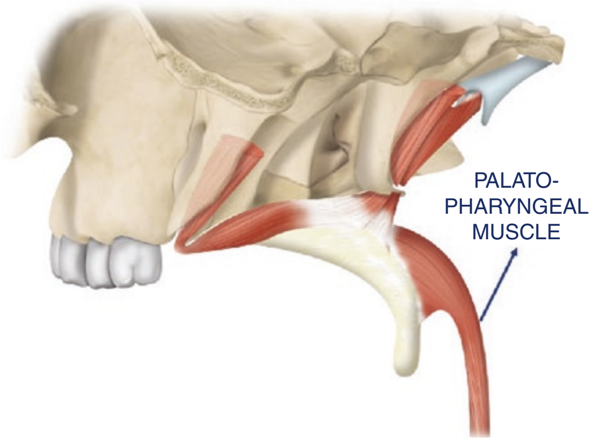

Fig. 7.5 Palatopharyngeus muscle (postero-lateral view)

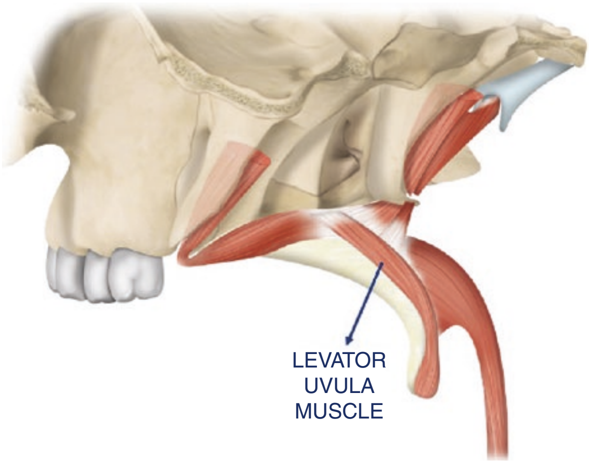

Fig. 7.6 Muscolaris uvulae (postero-lateral view)

palatine artery, which is a branch of the descending palatine artery (maxillary artery territory). The greater palatine artery travels anteriorly with the greater palatine nerve, along the junction between the hard palate and the alveolar process. It enters the incisive canal and ultimately anastamoses with septal branches of the sphenopalatine artery in the nasal cavity. The lesser palatine arteries contribute to the vascularization of this region and have anastomoses with the ascending pharyngeal (palatine branch), facial (ascending palatine branch), and dorsal lingual (tonsillar branch) arteries on the soft palate. Of note, the external carotid artery and the internal carotid artery, respectively, run approximately 1.8 cm and 2.1 cm from the lateral pharyngeal walls (Fig. 7.7) at the level of C2–C3; in up to 5% of patients the internal carotid artery is aberrant, running closely or even posteriorly to the pharynx [4].

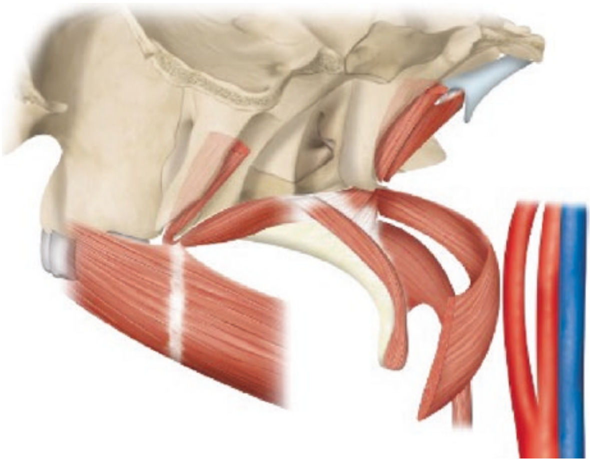

Fig. 7.7 Relationship between lateral pharyngeal wall and big vessels in the neck (postero-lateral view)

7.2.2 Palatine Tonsils

Relevant non-muscular structures of the oropharynx are lymphatic tissue aggregates: they are located in the pharyngeal (adenoid), tubal, palatine, and lingual tonsil regions, altogether known as Waldeyer's ring. The palatine tonsils are located in the fossa between the palatoglossal and palatopharyngeal arches (Fig. 7.1). The pharyngo-basilar fascia overlies the palatopharyngeus and superior constrictor muscles to create the tonsil bed. The dominant tonsillar blood supply is the tonsillar branch of the facial artery that travels through the superior constrictor muscle and enters the inferior tonsillar pole. Additional palatine tonsil blood supply includes tonsillar branches of the ascending and descending palatine, lingual, and ascending pharyngeal arteries.

Nerve branches from the glossopharyngeal, vagus, and pharyngeal plexi innervate the tonsils and pharyngeal arch.

7.2.3 Barbed Snore Surgery: Anatomical Consideration

In the attempt of summary, the LVP is the primary elevator of the velum, the PPM and PGM act as depressors, and all three muscles act to lengthen the velum. Movement of both the velum and pharyngeal walls contributes to normal velopharyngeal closure (Table 7.1).

The relation between the size of the velum and that of the oropharynx, as well as the slope of the posterior pharyngeal wall, determines their potential area of contact during velopharyngeal closure. Tucker Woodson described multiple anatomical phenotypes of the velopharyngeal airway (for more details we remand to the original paper), which appear to interact with both BMI and lateral wall features to determine Apnoea-Hypopnea Index (AHI) severity [2]. Previously, Moore has described patterns of pharyngeal narrowing (for more details we remand to the original paper) [5].

Table 7.1 Muscles of soft palate: origin, insertion, innervation, action

Muscle	Origin	Insertion	Innervation	Action
Tensor veli palatini[a]	Scaphoid fossa of medial pterygoid plate;spine of sphenoid;auditory tube cartilage	Palatine aponeurosis(tendon around hamulus)	CN V medial pterygoid n. via otic ganglion	Tenses soft palate and opens mouth of auditory tube during swallowing and yawning
Palatoglossus[a]	Palatine aponeurosis	Side of tongue	CN XI throught pharyngeal branch of vagus via pharyngeal plexus	Elevates posterior part of tongue and draws soft palate intu tongue
Palatopharyngeus[a]	Posterior boarder hard palate;palatine aponeurosis	Lateral wall of pharynx;thyroid cartilage posteriorly	CN XI throught pharyngeal branch of vagus via pharyngeal plexus	Tenses soft palate and pulls walls of pharynx superoanteriorly and medially during swallowing
Muscolaris uvulae	Posterior nasal spine; palatine aponeurosis	Mucosa of uvula	CN XI throught pharyngeal branch of vagus via pharyngeal plexus	Shorten uvula and pulls it anteriorly
Levator veli palatini	Cartilage of auditory tube;petrous part of the temporal bone	Palatine aponeurosis	CN XI throught pharyngeal branch of vagus via pharyngeal plexus	Elevates soft palate during swalloing and yawning

[a]*pharyngeal dilators*

For what is clear so far, the oropharyngeal complex involved in snoring lacks rigid support in adult humans, yet that is precisely the issue we need to address in patients affected by collapse of the upper airways [1]. However, how can we give support to structures in such an area? This matter is the core of Barbed Snore Surgery (BSS).

Extending our look to the surroundings, fibro-tendinous and bony structures that already serve as a scaffolding for the oropharynx are located nearby and deserve consideration: the pterygomandibular raphe, the pterygoid hamulus, the palatine aponeurosis, and the posterior nasal spine. Such structures represent a proper and constant anchoring area for soft tissues of the palate and lateral pharynx that need to be molded in our stitches-free Barbed Surgery.

7.2.3.1 Pterygomandibular Raphe

According to Howland and Brodie [6], the raphe was first described in 1784 as a sphenoid tendon coursing between the upper and lower jaws. Besides pterygomandibular raphe, it has been variously named as *ligamentum pterygomandibulare*, *ligamentum intermaxillaire* or *pterygomaxillaire*, "*aponeurose buccinatopharyngée,*" etc. The raphe is generally described in current textbooks as a narrow, tendinous band that courses from the apex of the hamulus of the medial pterygoid plate to the posterior aspect of the retromolar trigone of the mandible. This structure provides attachment to a portion of the buccinator muscle from its anterior border, while part of the superior pharyngeal constrictor takes origin from its posterior one [7]. Many anatomical atlases illustrate the raphe as such, therefore it has been thought to function as an anchor for the buccinator and superior pharyngeal constrictor muscles, that would enable each muscle to contract independently (Fig. 7.8).

The projection of the raphe is visible and palpable from within the oral cavity, just behind the retromolar trigone, where it is covered by mucosa that forms the vertical *pterygomandibular fold*. As mentioned above, the pterygomandibular folds are fundamental landmarks in Barbed Snore Surgery, since they represent the two pillars of the pharyngeal scaffold.

7.2.3.2 Pterygoid Hamulus

The *pterygoid hamulus* continues the medial lamella of the pterygoid process caudally, it is directed slightly outwards and forwards, and it usually ends in an approximately spherical tip (Fig. 7.9). The lowest and most anterior fibers of the levator veli palatini arise from the base of the pterygoid process, up to and a little beyond the base of the hamulus. The tendon of the TVP, which also arises from the base of the pterygoid process, surrounds the hamulus and is redirected medially [8].

The pterygoid hamulus is one of the most important and reliable structures in BSS, since it does not present frequent anatomical variants, thus its shape, position, and relationship to the nearby soft tissues are mostly constant.

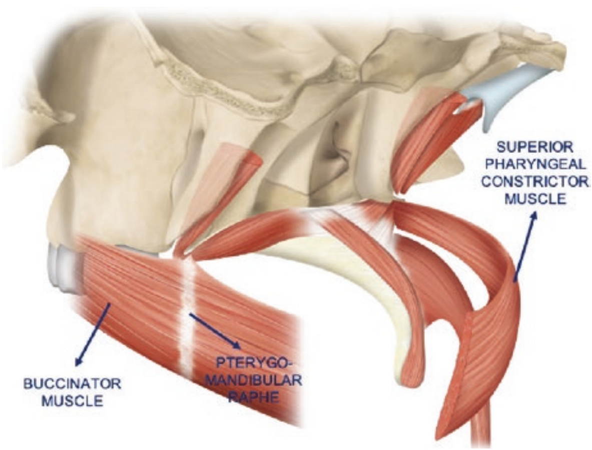

Fig. 7.8 Pterygomandibular raphe and its relationship with buccinator muscle and superior pharyngeal constrictor muscle (posterolateral view)

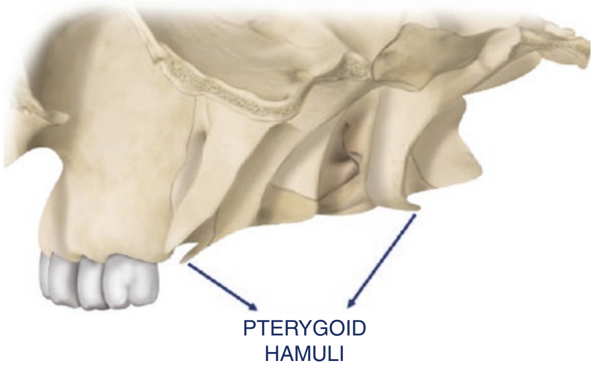

Fig. 7.9 Pterygoid hamulus (postero-lateral view)

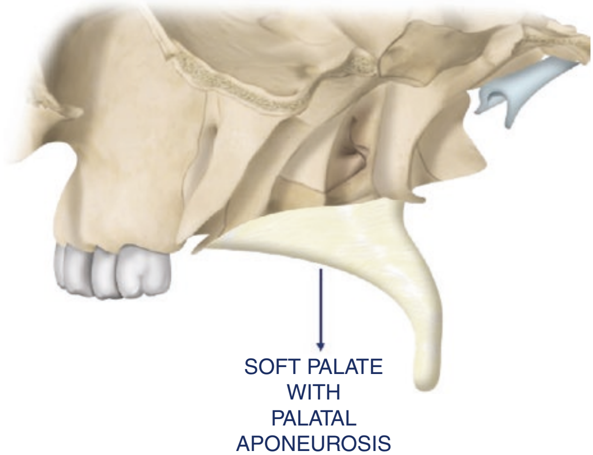

Fig. 7.10 Palatine aponeurosis (postero-lateral view)

7.2.3.3 Palatine Aponeurosis

The palatine aponeurosis is a distinct anatomical entity continuous with the periosteum of the nasal cavity. It is a tensor aponeurosis of connective tissue that connects the soft to the hard palate, extending posterior-inferiorly from the edge of the hard palate and posterior nasal spine, to a free margin (Fig. 7.10). It is also continuous with the lateral pharyngo-basilar fascia*, bilaterally continuous with the tendon of the TVP* spreading on the anterior border and inferior (oral) side of the palatal aponeurosis [3]. Some TVP's tendinous fibers terminated on the posterior border of the palatine bone.

7.2.3.4 Posterior Nasal Spine

The medial end of the posterior border of the horizontal plate of palatine bone is sharp and pointed, and, when united with that of the opposite bone, forms a projecting process, the **posterior nasal spine** for the attachment of the palatine aponeurosis and MU (Fig. 7.11) [1].

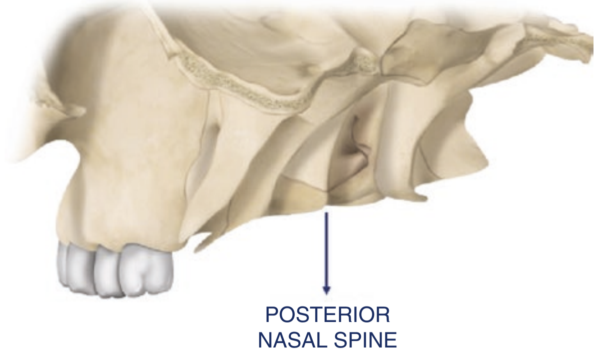

Fig. 7.11 Posterior nasal spine (postero-lateral view)

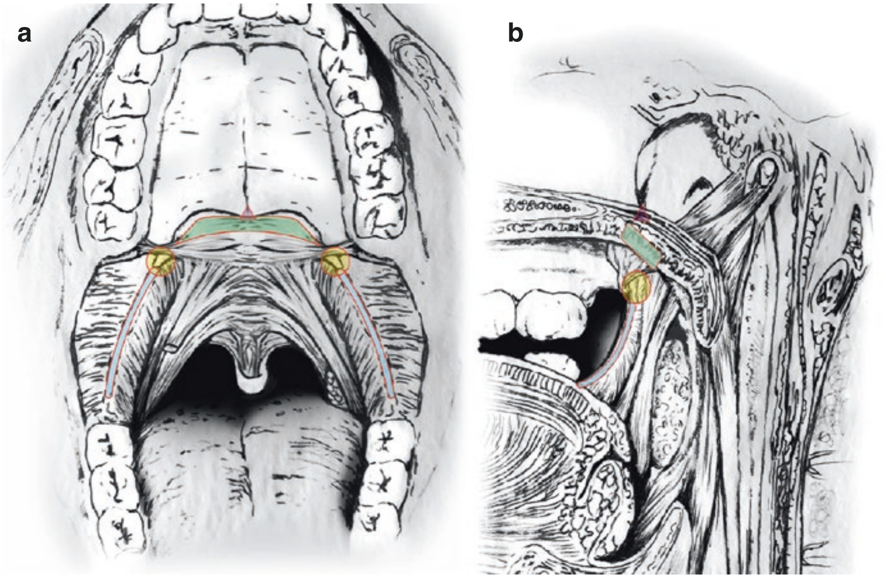

Fig. 7.12 *Arched pharyngeal Scaffold* in barbed surgery. (**a**) *Transoral view.* (**b**) *Lateral view.* Pterygomandibular raphe (Blue), pterygoid hamulus (Yellow), palatine aponeurosis (Green), posterior nasal spine (Pink)

The aforementioned ones form an ogival arched framework that on both sides is laterally bordered by the pterygomandibular raphe and unites the hamulus, the palatine aponeurosis, and the posterior nasal spine, from laterally to medially, respectively. At first, these structures representing the support of the Barbed Roman Blinds Technique (BRBT) [9] had been named “virtual curtain-rail” after their similarity to the curtain-rail that normally supports roman blinds. Nowadays, along with the evolution of the field of snore surgery, the concept of a monodimensional–bidirectional curtain-rail has been overcome. In its oblique fashion, this framework is directed from front to back and from lower to upper. Indeed, taking into account the three-dimensional and multidirectional shape of the pharyngeal framework, we can now refer to it as the **arched pharyngeal scaffold,** or simply **APS** (Fig. 7.12).

FOCUS ON: P.O.M.A.S.

The muscles of the soft palate and lateral pharyngeal walls are intermixed with each other in a fibrofatty layer. In the soft palate all the muscles are wrapped by the **palatal fascia (PF)**, located on the nasal side of the soft palate and originating from the fusion of the periosteum of the hard palate on its oral and nasal sides [3]. In oropharynx the muscles are enveloped between two fasciae, the **pharyngo-basilar fascia (PBF)** and the **bucco-pharyngeal fascia (BPF)**. The PBF is situated between the mucous and muscular layers and attaches the wall of the pharynx to the base of the cranium. The BPF covers the muscular layer of the pharynx and is continued forward onto the buccinator muscle, it forms the pterygomandibular raphe, providing attachment for the superior pharyngeal constrictor muscle (Fig. 7.13). Taking inspiration from the "S.M.A.S." (superficial muscular aponeurotic system) which is a continuous fibromuscular layer that envelopes the face and neck, described by Mitz and Peyronie in 1976 [10], this novel fascial system was named by Mario Mantovani the "**P.O.M.A.S.**" (palato-oropharyngeal musculoaponeurotic system) and it is composed by PF, FBF, and BPF [11]. In S.M.A.S. rhytidectomy, the lifting tension applied to the musculoaponeurotic system is transferred to the facial and cervical muscles [12] in the same way, taking advantage of the rigid fibro-osseus anchoring points (posterior nasal spine, pterygoid hamulus, pterygomandibular raphe, palatine aponeurosis), the barbed sutures manage to stiffen and lift the P.O.M.A.S. and thus obtaining a comprehensive modification of the position and tension of the pharyngeal walls. The surgical increase of the basal tension of the P.O.M.A.S. can contrast the collapsibility of pharyngeal walls, preserving the anatomic and functional integrity of muscle components.

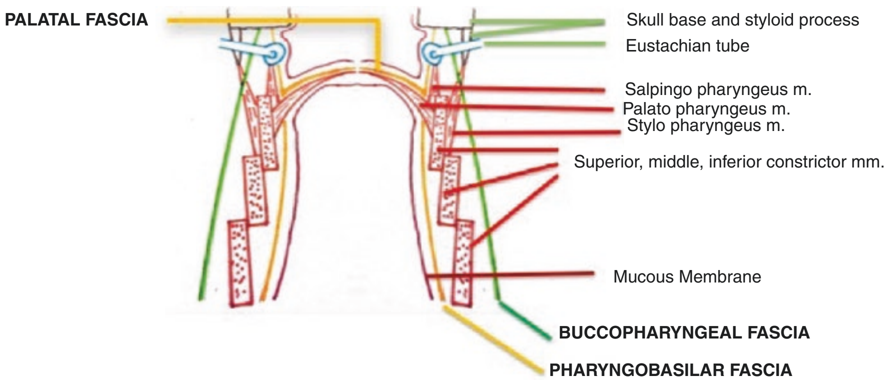

Fig. 7.13 Schematic coronal view of P.O.M.A.S (palatal fascia, pharyngo-basilar fascia, and bucco-pharyngeal fascia) enveloping the palato-oropharyngeal muscles

Acknowledgments Francesca Pirola, MD helped with English revision of the chapter.

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8 Surgical Simulation for Barbed Pharyngoplasties

Vittorio Rinaldi and Lorenzo Pignataro

8.1 Background

Barbed pharyngoplasty (BP) has become popular for the surgical treatment of obstructive sleep apnea (OSA) and is an innovative, effective, and minimally invasive surgical strategy. Mastering both the correct use of the barbed sutures and the surgical steps required to remodel the palato-oropharyngeal anatomical structures is key for this surgery. However, the learning curve is steep due to the limited surgical oropharyngeal workspace.

Human cadaver surgical skills training offers the highest-fidelity simulation of the operating environment, but unfortunately the cost of biologic samples is prohibitive for many residency programs; furthermore, the availability of fresh human cadavers is limited by ethical and regulatory issues.

For this reason, low-cost, easy-to-build, and easy-to-handle synthetic surgical models reproducing the palato-oropharyngeal anatomy were developed to expedite the BP surgical learning curve of residents and fellows when fresh frozen cadaveric specimens are not available [1].

If learning BP on a synthetic model is not realistic enough, ex vivo animal specimens are another inexpensive, easily available, and repeatable solution. Compared to synthetic models, the animal model appears to be superior in terms of tissue quality and tactile feedback to the operator during surgical simulation [2].

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_8

8.2 Synthetic Models

The “Barbed Snore Surgery Simulator” (Fig. 8.1) designed by Rinaldi et al. [1] is a simple model mainly consisting of two components:

– a finely detailed resin skeleton, the same size as an adult male skull, with the mandible fixed bilaterally with screws to the glenoid fossa allowing for adjustable inter-incisor distance;
– a synthetic soft palate, manually shaped from a three-layer (simulating mucosal, submucosal, and muscular layers) silicone model (approximately 3 × 4 × 1 cm) and glued onto the resin skeleton.

Due to difficulties in reproducing the soft tissue composing the lateral pharyngeal walls, the Barbed Snore Surgery Simulator was designed to provide a realist training model for BPs mainly addressing the soft palate, such as barbed anterior pharyngoplasty [3–5], which is usually performed in case of antero-posterior retropalatal collapse in drug-induced sleep endoscopy (DISE).

The advantages of the Barbed Snore Surgery Simulator are: the possibility of directly seeing the surgical bony landmarks (PNS, PH, PR), which are invisible and only palpable during real surgery; the possibility of practicing in a narrow operating field, as the simulator, despite the absence of the tongue in the model, is absolutely comparable to the majority of adult OSA patients undergoing BP; the adjustable

Fig. 8.1 The Barbed Snore Surgery Simulator

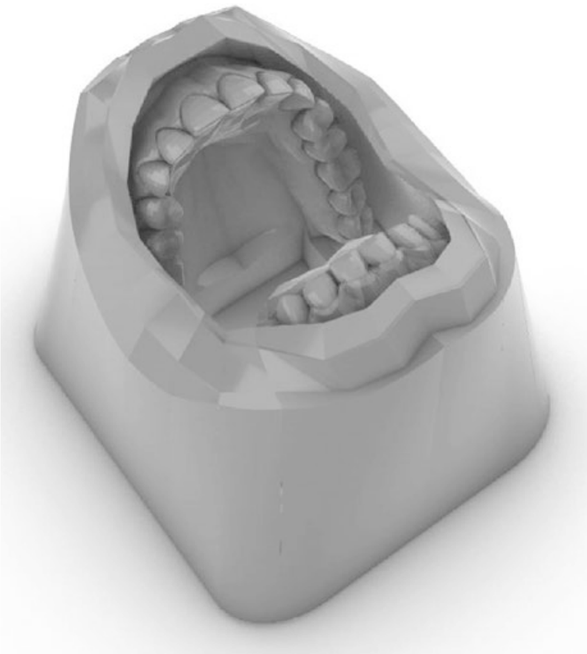

Fig. 8.2 A prototype of a new synthetic simulator for pharyngoplasty (under development)

mandible position allows surgical difficulty to be increased by simply narrowing the inter-incisor distance; the reduced cost and time to assemble the simulator, with components readily available at most popular online retailers; and the possibility of replacing the soft palatal component after completing the simulation allows unlimited repeats of the procedure on the same simulator.

The main limitations of a synthetic model are the inability to imitate the complexity of organic tissues (in particular the tactile and resistance characteristics of real tissue) and the limited exposure to anatomical variants.

Figure 8.2 shows in preview the first prototype of a new synthetic simulator for pharyngoplasty, developed together with Dr. Giovanni Mancini (Rome, Italy), Dr. Marina Carrasco and the Engineer Fernando Torres-Caballero (Valencia, Spain), which will provide more anatomical details and will allow the operator to work even on the lateral pharyngeal walls, thus simulating different pharyngoplasty techniques such as Alianza, Barbed Reposition Pharyngoplasty, Modified Reposition Pharyngoplasty, Expansion Sphincter Pharyngoplasty, etc. [6–9].

8.3 Ex Vivo Surgical Model

Several otolaryngology-head and neck surgical procedures can be simulated using ex vivo ovine models [10, 11]. Fresh ovine specimens are widely available at very low cost and Rinaldi et al. [2] have proven them to be extremely efficient in fulfilling the goals of BP training, namely to improve confidence with barbed sutures and provide tissue consistency in a small surgical field with the possibility of learning to work with real surgical palatal anchoring points (PNS, PH, PR).

In order to reproduce realistic anatomical conditions, the lamb head should be stored at 4 °C for at least 3 days to minimize the post-mortem rigor mortis (trismus) and facilitate jaw opening and oropharynx exposure during the training session; the muzzle should be dissected on the coronal plane to reduce the oral cavity depth, which is otherwise larger than that in humans; a small transversal cut on both cheeks can facilitate the maneuverability of surgical instruments. The prepared head is then placed on a table and the surgical field is exposed by means of a surgical mouth gag (Fig. 8.3). Despite proportional and anatomical differences, all BP techniques can be successfully simulated (e.g., Barbed Anterior Pharyngoplasty, Barbed Roman Blinds Technique, Alianza Technique, Barbed Reposition Pharyngoplasty) [3–9, 12].

The advantages of an ex vivo surgical model are: it can provide inexpensive, realistic, easily repeatable palatal surgical training; the possibility of practicing in a narrow operating field which faithfully reproduces the human surgical field, providing realistic and challenging maneuvering of the hands and so improving surgical skills even on the lateral pharyngeal walls; ovine specimens are easy to find (abattoir or butcher) and inexpensive (approximately $5 each); and tissue consistency and the presence of all anatomical landmarks provide adequate surgical simulation.

The main limitations are: the differences in proportions compared to human anatomy, with the ovine head presenting a proportionally greater palatal length; the different anatomical pharyngeal configuration with a globally shorter and narrower ovine pharynx with the epiglottis closer and interlocked to the soft palate due to its more cranial location; the need for adequate preparation of the specimen prior to the

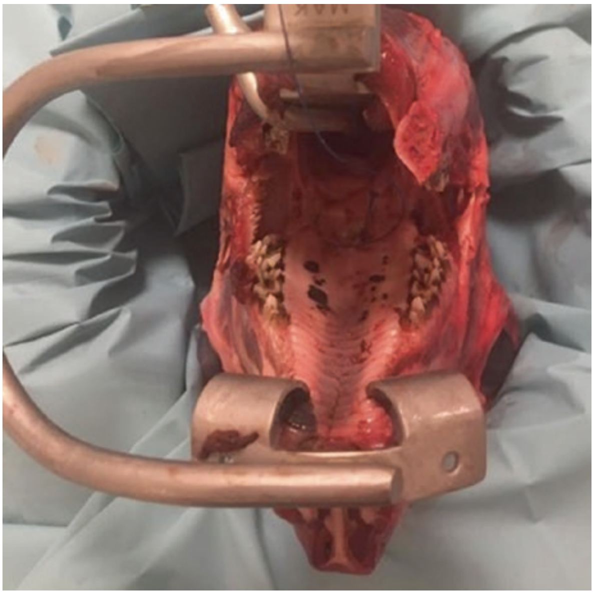

Fig. 8.3 Ex vivo ovine model for barbed pharyngoplasty. The surgical field is exposed by means of a surgical mouth gag

training session; and compared with real surgery, an ex vivo model is obviously limited by the absence of swelling and bleeding following manipulation and lack of fragility of tissues.

8.4 Take Home Messages

Training competent and professional surgeons efficiently and effectively requires innovation and modernization of educational methods [13]. With the growth of technology and the decrease in hands-on experience, there has been an increase in interest in using simulation.

The acquisition of surgical skills requires consistent practice, and evidence suggests that many of the technical skills can be learned away from the operating theater [14]. In addition, the more skilled surgeons could benefit from training in new techniques and technologies.

Palato-oropharyngeal remodeling surgery has become central in OSA surgical management and BPs are innovative techniques in this field. The use of barbed sutures allows the surgeon to lift and stiffen the soft palate and lateral pharyngeal walls to counter their hyper-collapsibility during sleep while preserving their anatomical and functional integrity.

The learning curve for BP is steep and success is conditional on the correct use of the barbed sutures and the careful application of the surgical steps in a narrow surgical field. The use of synthetic models may be conveniently and safely employed for hands-on surgical practice in BP. The Barbed Snore Surgery Simulator is the first surgical model that provides realistic, low-cost, and easily repeatable training for BP. New synthetic simulators are being developed which will allow the trainee to work even on the lateral pharyngeal walls. These new improved simulators also provide more anatomical details and synthetic tissue more comparable in feel and use to real conditions.

Although no animal can perfectly simulate human anatomy, the ex vivo ovine model has proved to be a valid and effective surgical model for teaching and increasing the use of BP.

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9 New Philosophy in Palate-Oropharynx Procedures

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In this chapter we aim to describe the diagnostic and therapeutic path that, after many years of experience, has led us to the current new philosophy in the approach and treatment of snoring and obstructive sleep disorders. In this journey, at a certain point, we met our friend Prof. Mario Mantovani who contributed well to the development of this new mentality.

The most experienced otolaryngologists have certainly seen an important evolution in snoring and obstructive sleep apnea treatment over the past 40 years. From widely resective surgical techniques of the pharynx and soft palate, the same for all patients, we have now arrived at a much more precise surgery, tailored to each case and with decidedly better final results. But things have also changed a lot from the diagnostic point of view with sleep endoscopy and, recently, with phenotyping (pathophysiological and polysomnographic): all this helps us to operate the right patient with the most appropriate technique.

Supplementary Information The online version contains supplementary material available at [https://doi.org/10.1007/978-3-030-96169-5_9].

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*, https://doi.org/10.1007/978-3-030-96169-5_9

In this clinical path the figure of Prof. Mario Mantovani plays an innovative role in the surgical field: he gave birth to the "barbed revolution."

Four fundamental stages led us to the new philosophy of procedures for the palate and oropharynx:

- Introduction of DISE (Drug Induced Sleep Endoscopy) [1–4].
- Design of non-resective but functional techniques [5–11].
- Idea of using barbed sutures in this particular surgery [12–19].
- Phenotyping for a more accurate choice of therapy [20–23].

Let us now briefly analyze these steps.

From a diagnostic point of view, a fundamental stage of our clinical path was the introduction of Drug Induced Sleep Endoscopy (DISE) which we started to perform in 2006 (Figs. 9.1 and 9.2). Finally, it was possible to observe and record mechanical and acoustic phenomena during almost physiological sleep in the first airways for each patient. We too, like other authors, soon found that the DISE results did not fully agree with the Muller maneuver.

Since then, DISE has become an indispensable preoperative diagnostic for us. Furthermore, it also allows us to evaluate the possibility of alternative or complementary treatments to surgery.

Instead, from the surgical point of view, the other fundamental step towards the current philosophy was the introduction of non-resective surgical techniques, aimed at the functional expansion of the oropharyngeal sphincter. We immediately understood the value of this surgical evolution and since 2010 we have abandoned

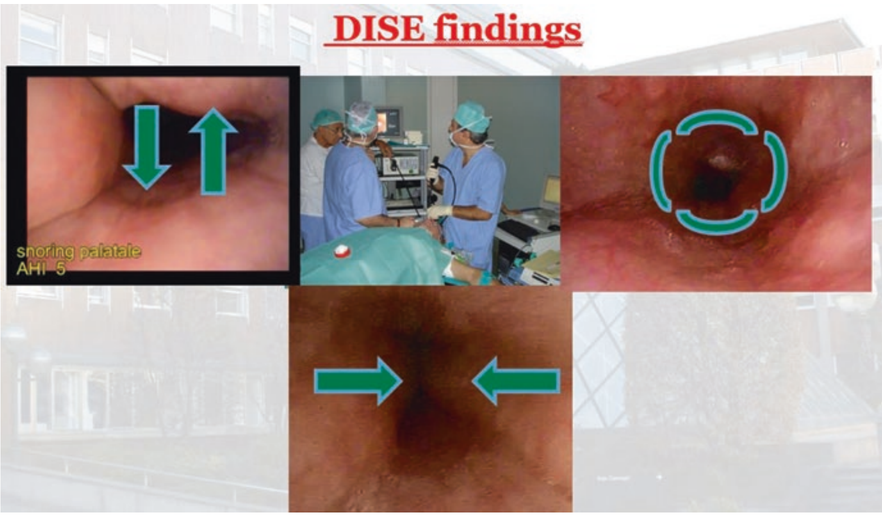

Fig. 9.1 DISE occlusion patterns

Fig. 9.2 DISE

the resective techniques (uvulo-palato-pharyngoplasty or UPPP) (Fig. 9.3) to focus on these new surgical interventions (anterior pharyngoplasty and lateral pharyngoplasty).

The functional results were very satisfactory. At the same time, we found a reduction in patient discomfort and a greater acceptability of surgical treatment.

The third element that led us to our current modality of surgical treatment of snoring and obstructive sleep apnea was the introduction of barbed sutures applied to functional expansion surgery that we have performed since 2010.

In recent years, our interest has been increasingly oriented towards the phenotyping of our patients based on the recent scientific works of Marcello Bosi, a pulmonologist who has dealt with a lot of these aspects. In fact, thanks to a more in-depth reading of the polysomnographic data and the use of some clinical criteria, it is possible to classify patients in a more complete way and not only on the basis of the severity of the AHI values.

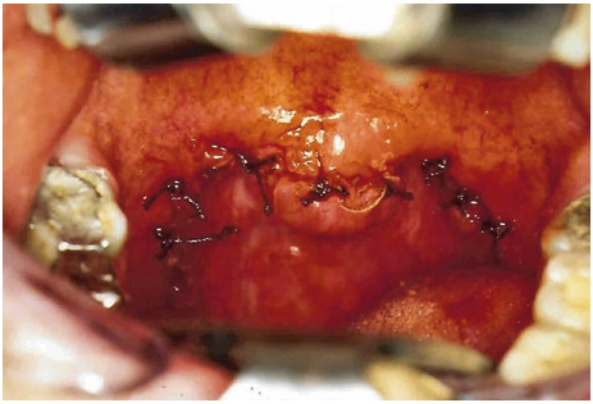

Fig. 9.3 UPPP

The main objective is to better select the cases to undergo surgery by identifying, above all, patients with high collapse that correspond to PALM 1 and 2 of the PALM scale.

Now let us talk in more detail about our experience with Prof. Mantovani and the Polyclinic of Milan (Director Prof. Lorenzo Pignataro). Prof. Mario Mantovani at the Polyclinic of Milan had the great revolutionary idea of using this new type of suture threads in this area, and together with his director Prof. Lorenzo Pignataro immediately engaged in the search for the best method of application.

Our Osa Center, at Humanitas San Pio X Hospital, has already existed in Milan since 1994, with ENT coordination, directed by Prof. Fabrizio Salamanca. This center has always had an important clinical activity in the field of diagnostics and surgery of snoring and obstructive sleep apnea.

For an accurate evaluation of the feasibility of Prof. Mantovani's intuition, the two Milan hospitals worked together and had a first great experience from 2012 to 2016. Together we found the feasibility and safety of these new procedures. Already in 2014 we presented the first results at a congress that was held in Humanitas San Pio X Milan (Fig. 9.4) (the video reports of the organizers subtitled in English are attached—Videos 9.1, 9.2, and 9.3).

The acronym BSS (Barbed Snore Surgery) was created by Dr. Fabrizio Costantini precisely to give a title to this conference. That was the first time in the world that BSS was publicly talked about.

On that occasion, a review of the case series compared to the results of the new barbed surgery had immediately confirmed a significant improvement (Fig. 9.5).

In fact, some of the well-known drawbacks of traditional surgery have been brilliantly overcome by the use of this type of wire: absence of knots, homogeneous distribution of the suture tension, and possibility of anchoring the soft tissues involved in the suture to adjacent more rigid structures (palatine aponeurosis, pterygoid hamulus, pterygomandibular raphe).

Prof. Mantovani's great curiosity and genius were applied to traditional surgery for snoring and obstructive sleep apnea. From 2012 4 years of intense work began, with continuous and daily brainstorming, an exciting experience for all of

Fig. 9.4 2014 Conference

us that led us to design our first surgical techniques such as BAPh (Barbed Anterior Pharyngoplasty): the Barbed Roman Blinds Technique (BRBT) had already been conceived by Mantovani and collaborators in 2011, as an evolution of RBT—Roman Blinds Technique (incidentally, the Roman Blind Technique was also presented in Humanitas San Pio X in 2010 during another congress organized by Prof. Salamanca) (Fig. 9.6) (Video 9.4).

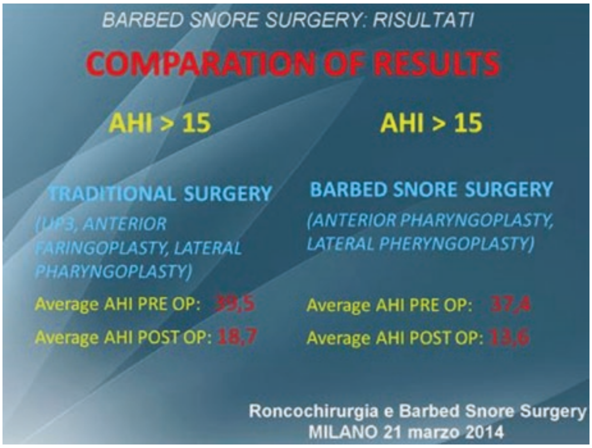

Fig. 9.5 First results

Fig. 9.6 2010 Conference

Together we overcame the first fears and uncertainties, we tried to understand which was the best size of the threads to use that he would be able to ensure a good seal without causing significant inflammation of the oropharynx and soft palate. We have moved with great caution since we were the first in the world to use these barbed sutures on a large scale in this surgery. The use of these self-locking threads did not represent an *off label* use, as they have been approved precisely for soft tissue sutures: although these threads were not "off label," we took care to proceed slowly and always supported by the Specialist (Dr. Chiara Sgarbi) of American Company Quill's which at that time produced the bidirectional self-locking thread that we used.

The introduction of barbed sutures in this area has further allowed a less invasive and more functional surgery. The cornerstones and inclusion criteria of traditional pharyngo-palatal surgery have not changed.

Our many years of experience (since 2012 all pharyngo-palatal surgical procedures have been performed in barbed mode) have shown us that the learning curve of these techniques is quite easy even for less experienced surgeons, especially if supported by senior surgeons.

One of our initial concerns was to always be sure that the suture was entirely internal, with no exposed sections of thread to the point of avoiding possible routes of penetration of infectious agents. Daily practice, however, has taught us that even if, during the post-operative course, sections of thread become superficial, there are no problems either from the infectious point of view or from the point of view of the final result.

Another possibility is not performing the tonsillectomy in front of a tonsillar grading of 1. We noticed an immediate good lifting and a good expansion of the oropharyngeal sphincter when we engaged the tissue with these new sutures. However, we had to change our mind because if the tonsillectomy is not performed, the part of post-operative scar fibrosis that stabilizes the operated anatomical district is missing; besides, often the post-operative tonsillar dimensions are decidedly superior to the clinical grading and therefore the tonsillectomy often allows a further extension of airway space.

We always use threads with a complete resorption time of about 6 months (polydioxanone): therefore, the final result, which persists well beyond the resorption time, is due to the scar fibrosis that occurs around the suture, thus creating a fibrous tensil structure within the operated area.

Fibrosis is created because the thread induces an inflammatory reaction from a foreign body: the larger the thread and the more sections of the thread are present, the greater the inflammatory reaction: it is therefore necessary to find a balance between the need to stiffen the soft tissues and not create significant discomfort and pain for the patient. It is sufficient that these threads keep the suture unaltered for at least 3–4 weeks to achieve a good architecture of the scarring process. After such an interval of time, if some stretch of externalized thread disturbs the patient, they can be safely removed without interfering with the already advanced scarring process. We have verified that after 3–4 months in correspondence with the various intratissue passages of the threads, it is possible to palpate hard-elastic cords.

Until now, we have not felt the need to use non-absorbable threads as we are satisfied with the current results and also to avoid a possible greater discomfort for the patient in the medium and long term which could perhaps lead to the need to remove the suture with great difficulty and with the risk of permanently damaging such an important functional area.

At the beginning of our experience we had some difficulties in using the normal surgical needle holders that we had available: we were unable to hold firmly the needle (atraumatic and conical) during the suture because it often changed direction. However, it is very important that the needle does not change direction suddenly because most of the suture is performed in a covered way and we are working close to sensitive structures. We solved the problem by having manufactured needle holders like metal thread wrenches which have a very secure hold on any type of needle. We have never had the need to carry out important hemostasis because the various bleeding that occurs is totally controlled with a good engagement of the tissues.

Other technical notes of surgical execution at our center that we have been adopting for years, even before 2012, are:

- We perform tonsillectomy with the Quantum Molecular Resonance which helps us not to overheat the muscles of tonsillar lodge (58 °C) it in order not to engage tissues with a good probability of post-operative necrosis. We would lose all the advantages of homogeneous distribution of the tension given by the barbed wires.
- The preparation of the muscle flaps (e.g. of the palato-pharyngeal) or the excision of mucosa and submucosa (e.g. BAPh) is performed with a low-power (1.5 W) super pulsed CO_2 laser: to have a precise packaging of the flap looking for not to exceed 100 °C. In this case, we favor precision over operating temperatures.

We then came to perfect the surgical planning by deciding to perform specific barbed techniques for the different obstruction and vibration patterns (anteroposterior, lateral-lateral, circular) reaching the so-called Custom Made BSS. DISE guides us on the type of tension vectors to be applied while performing suture in order to optimally oppose to the collapse and vibration of the oropharyngeal soft tissues.

For each case we prepare, in view of the intervention, a graphic project showing the paths that the suture should follow and any excision areas, including tonsillectomy (Figs. 9.7, 9.8, and 9.9).

Still in the context of Custom Made Barbed Snore Surgery, we also decide to use different self-locking threads based on the technique we plan to adopt for each case.

As mentioned, we always use absorbable threads, sometimes bidirectional and sometimes unidirectional.

As bidirectional we usually use Stratafix J&J, a synthetic absorbable monofilament in Polydioxanone, measuring 0.24 + 24 cm as the length of the barbed suture with ½ circle of 36 mm for the atraumatic-conical needle (Fig. 9.10).

As unidirectional we usually use V-Loc T90 Covidien, a synthetic absorbable monofilament in Polydioxanone, measuring 2-0, 30 cm long, with ½ circle of 27 mm as atraumatic-conical needle.

The two strands also differ in the shape of the beards (Fig. 9.11).

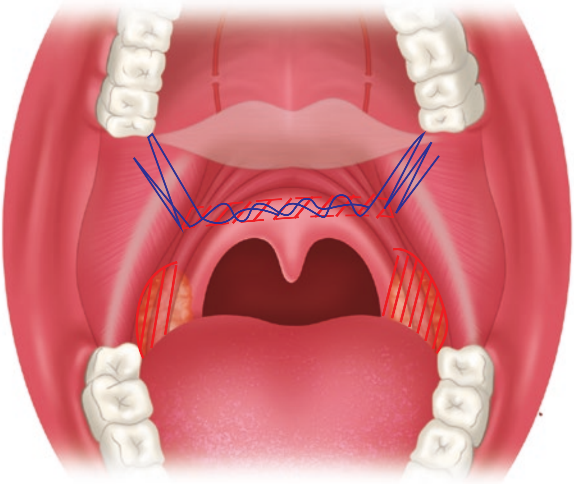

Fig. 9.7 Planning of barbed anterior pharyngoplasty

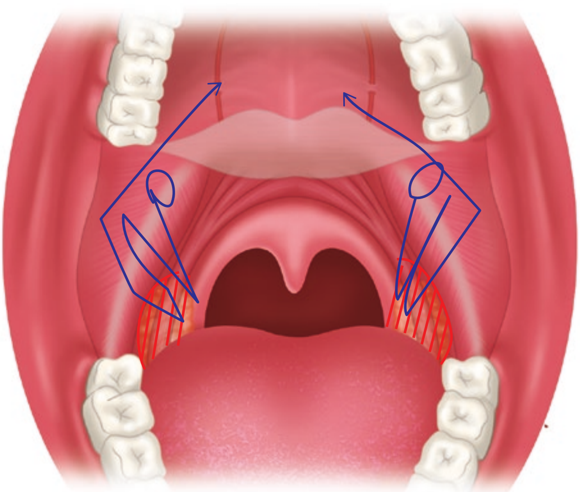

Fig. 9.8 Planning of barbed lateral pharyngoplasty with unidiretional thread

The bidirectional tread we use has acute barbs, formed by a single cut of the thread during production, arranged in a helical manner over the entire extension of the thread except in the central area (Fig. 9.12): the point of inversion of the barbs, which presents itself without barbs for a short distance and which represents the point of tension and holds between them of the two sections of thread with different direction of the barbs.

The unidirectional, however, has less sharp but thicker barbs, formed through a double cutting angle during production, also arranged in a helical manner (Fig. 9.13)

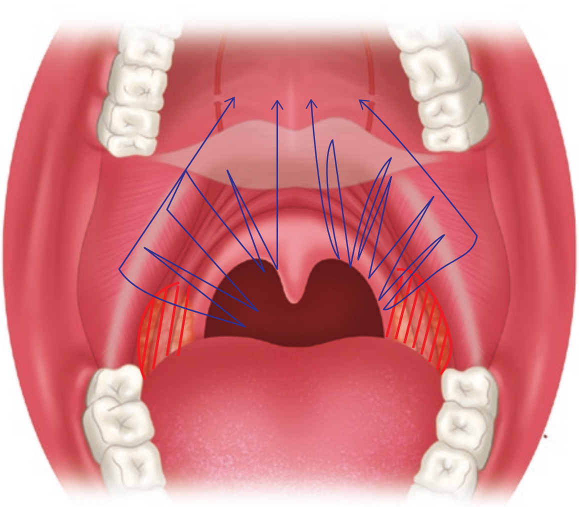

Fig. 9.9 Planning of barbed lateral pharyngoplasty with bidirectional thread

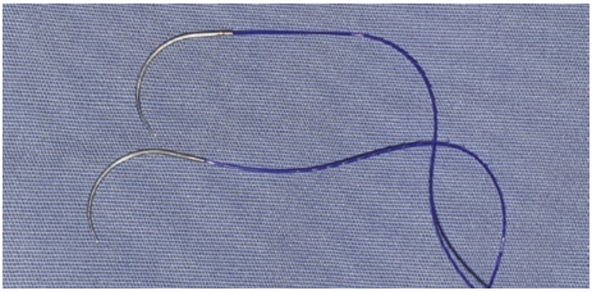

Fig. 9.10 The bidirectional thread

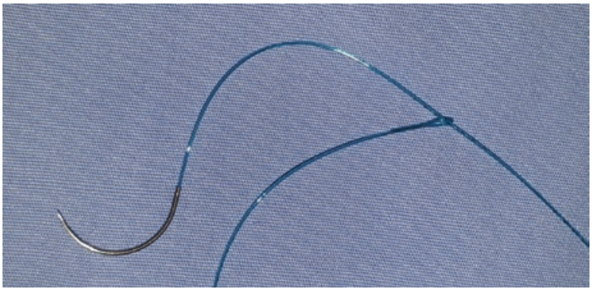

Fig. 9.11 Unidirectional threads

and the sealing point of the suture is represented by an eyelet, which remains external to the suture.

We base the choice of thread as a guideline for the type of intervention:

- The bidirectional is used in Barbed Anterior Pharyngoplasty (BAPh), and in the circular ones such as Barbed Antero-Lateral Pharyngoplasty (BALPh) and in Alianza (Barbed Roman Blinds Technique + BAPh).
- The unidirectional is used in Barbed Lateral Pharyngoplasty (BLPh).

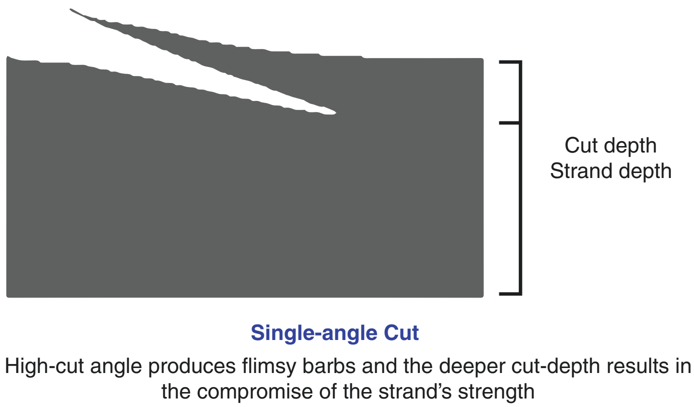

Fig. 9.12 Barb of bidirectional thread

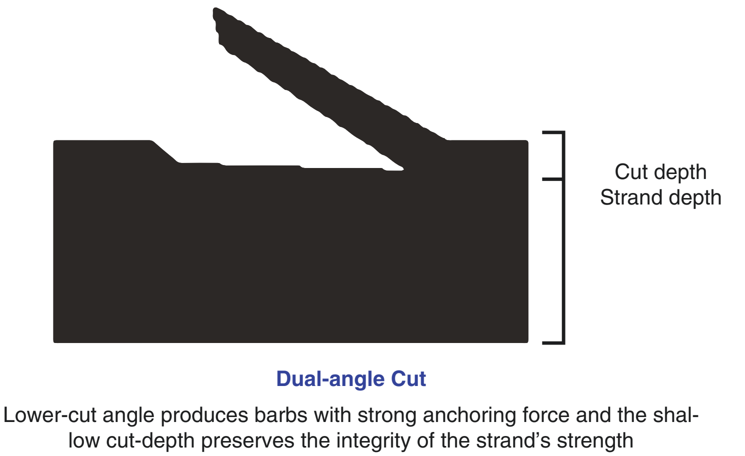

Fig. 9.13 Barb of unidirectional thread

Thanks again to the great idea of Prof. M. Mantovani, using these threads that do not need to be knotted, we realized the possibility of exploiting more rigid anatomical structures adjacent to the surgical area to increase the stability of the oropharyngeal soft tissues put under tension. It is thus possible to start the various passages of the suture from any anchor point and finish them in another area, even at a distance, because there is no need to tie the ends of the thread.

Thus was born the idea of what we have called VIRTUAL CURTAIN RAIL (Fig. 9.14) which is formed by anatomical structures adjacent to each other.

The structures identified are:

1. Posterior nasal spine/palatine aponeurosis
2. Pterygomandibular Raphe
3. Pterygoid Hamulus area

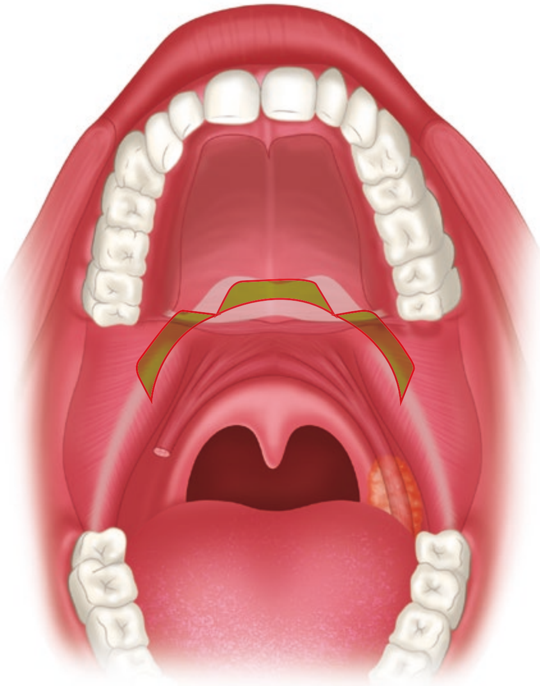

Fig. 9.14 Virtual curtain rail

The layout of these structures creates an anatomical semicircle that surrounds the oropharyngeal surgical region for its entire extension. It is possible to pass the self-locking wires inside these more stable structures, thus placing the engagement barbs in areas of rigidity and stability. We thus have reference points available that allow us to apply the expansion vectors as best needed to reach the best opening and stiffening suitable for each case.

It can certainly be said that for our Center the combination of the Drug Induced Sleep Endoscopy, the use of barbed wires, and the "discovery" of the Virtual Curtain Rail have been revolutionary in the approach to surgery and in the development of really Custom Made surgical and therapeutic planning.

Always referring to the new philosophy within this branch of surgery, in recent years we have also changed the timing of the implementation of the DISE.

Until a few years ago, the DISE was sometimes performed in the same operating session, immediately before the surgical procedure (already partly decided on the basis of the physical examination) in order to have a better indication of the type of intervention according to the specific closure and vibration patterns. We have realized over time that the patients who did not see the DISE video before the procedure could not fully understand what we would perform from the surgical point of view.

Therefore, now we always execute DISE at a time other than the surgical one. We usually do it in the morning, in Day Hospital modality and then we see the patient again on another day to show him the video, to present the various multidisciplinary therapeutic options, to explain the surgical technique. It is therefore possible to achieve a valid and reasoned informed consent. The therapeutic planning is countersigned by both the doctor and the patient.

We have been implementing this consent acquisition procedure for about 5 years and we have noticed a greater adherence by patients to therapies proposed and decided together.

9.1 Two Coaxial Tubes Theory

In 2010 Mario Mantovani described the concept that the upper airways can be considered as a complex structure consisting of two coaxial tubes: a rigid outer tube, made of bony and fibrous tissues (hard palate, hamuli pterygoidei, pterygomandibular raphes, palatine aponeurosis), and a soft inner tube composed by a "passive" static component (pharyngeal mucosa and submucosa, annexed salivary glands, lymphatic and adipose tissue) and an "active" dynamic muscular component (palatal, pharyngeal, and lingual muscles) controlled by the central nervous system.

The activity of the muscular component of the inner tube may become inadequate during sleep, thus explaining the inspiratory upper airways vibration and collapse (velopharyngeal, retrolingual, and laryngeal) responsible for snoring and obstructive sleep apnea/hypopnea syndrome (OSAHS) and detectable during drug induced sleep endoscopy (DISE) [12].

Assuming that to date it is not possible to remodel the activity of the central nervous system during sleep, in order to contrast the collapsibility of inner tube we had the idea of transferring the rigidity of the outer tube to the inner tube using the barbed sutures.

Mario Mantovani used to explain the two coaxial tube theory with the similitude of "***the straw in the glass***." Let us imagine we have a straw in a glass (Fig. 9.15), if the walls of the straw (the UA inner tube) are enough rigid to resist the inspiratory negative pressure without collapsing, the beverage contained in the glass (air) will freely reach the mouth (lungs). Now let us assume that a tract of the straw (the palato-pharyngeal region) is overly soft, the result is that it will collapse under the negative pressure (Fig. 9.16). If we simply enlarge the collapsible tract of the straw (the goal of the old resective surgical techniques), without modifying the parietal tension, we will observe again a collapse at that level (Fig. 9.17). Now let us imagine this tract of the straw as made of two coaxial tubes, not reciprocally interconnected, having different collapsibilities: a rigid outer tube and a collapsible inner tube. The soft inner tube will anyway collapse under negative pressure (Fig. 9.18). If we fill the space between the two tubes with glue (barbed sutures), we will transfer the rigidity of the outer tube to the inner tube (Barbed Snore Surgery), which will be now able to resist the negative pressure (Fig. 9.19).

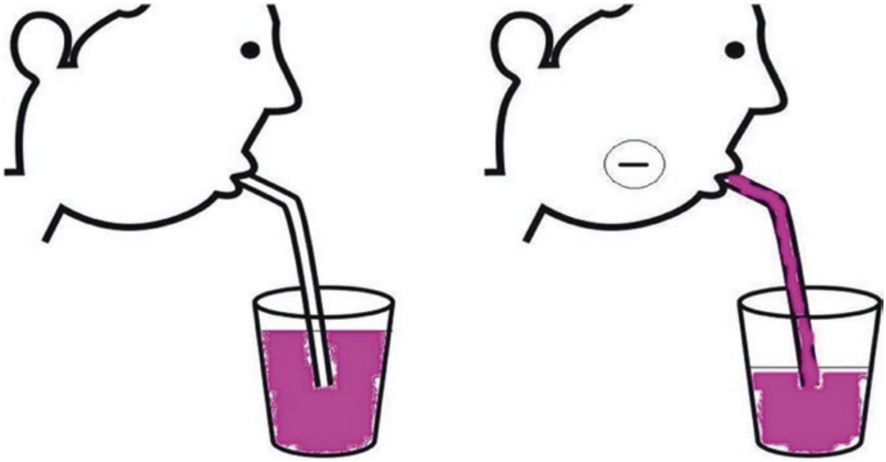

Fig. 9.15 The similitude of "**the straw in the glass**." The violet liquid in the glass represents the air, while the straw and the mouth exemplify, respectively, the upper airways (the inner tube) and the lungs

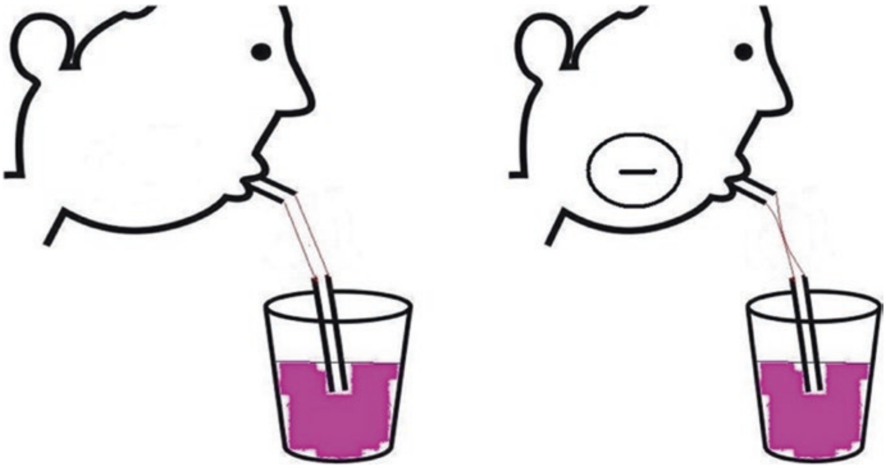

Fig. 9.16 If a tract of the straw (the velopharyngeal region) is overly soft, it will collapse under the negative pressure (OSAHS-associated velopharyngeal collapse)

It is therefore clear that the goal is to increase the basal tension of the muscle component of the velopharyngeal region (inner tube) by tensioning and suspending it to the surrounding rigid footholds (posterior nasal spine, hamuli pterygoidei, pterygomandibular raphes) of the outer tube, contrasting the collapsibility induced by the negative inspiratory pressure while preserving the anatomical and functional integrity of the muscle component.

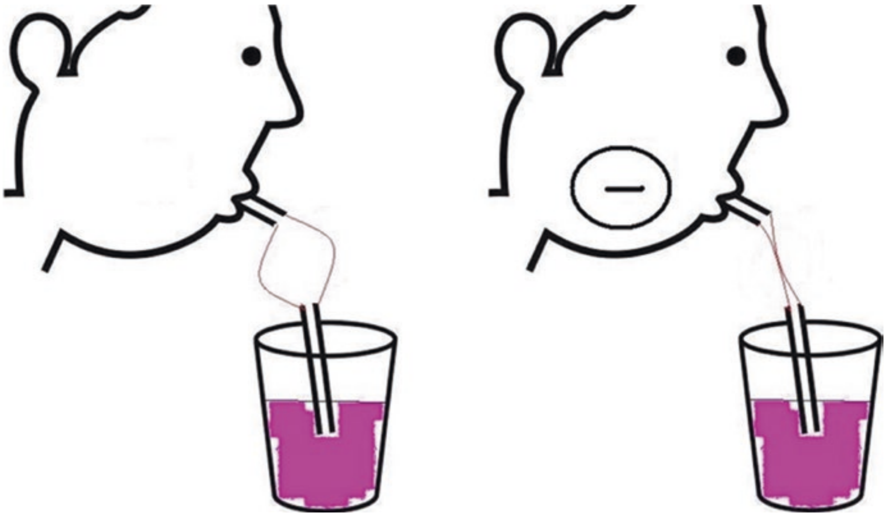

Fig. 9.17 If the collapsible tract of the straw is made larger without increasing its rigidity, it will collapse anyway (OSAHS-associated velopharyngeal collapse)

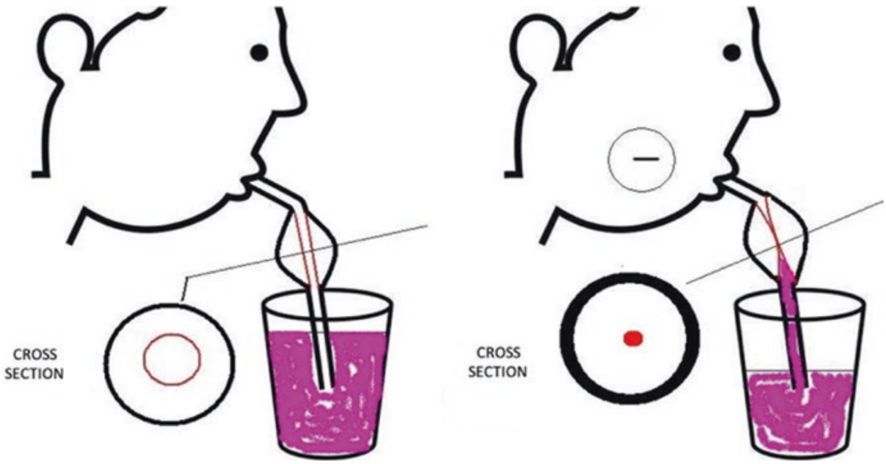

Fig. 9.18 If the soft tract of the straw consists of two coaxial tubes, a rigid outer tube and a collapsible inner tube, the latter will inevitably collapse under negative pressure (OSAHS-associated velopharyngeal collapse)

We developed an innovative surgical approach for retropalatal snoring and OSAHS, the Barbed Snore Surgery (BSS), customizable to anatomical and DISE findings (site and pattern of vibration and/or collapse). This modular approach consists of the following techniques: the Barbed Roman Blinds Technique (BRBT), the Barbed Anterior Pharyngoplasty (BAPh), the Alianza Technique (combination of BRBT + BAPh), and the Barbed Lateral Pharyngoplasty (BLPh). The BSS can be integrated in a multilevel surgical program [12, 13, 24, 25].

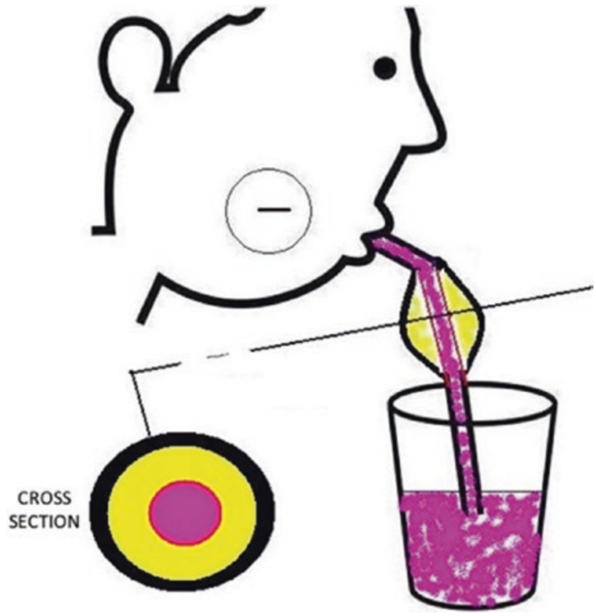

Fig. 9.19 If we paste the two tubes with some glue (yellow), we will get the stiffening of the walls of the inner tube (velopharyngeal region) which will contrast the collapsibility induced by the negative pressure (OSAHS-associated velopharyngeal collapse), allowing the liquid (air) to enter the mouth (lungs)

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Barbed Anterior Pharyngoplasty

10

Giulia Anna Marciante, Silvia De Santi,
and Fabrizio Salamanca

10.1 Introduction

Barbed anterior pharyngoplasty represents the evolution of several techniques proposed over the years. Expansion sphincter pharyngoplasty was first technique described in 2007 by Pang and Woodson [1]. This procedure was meant to treat respiratory obstruction due to palatal collapse by means of dissection of the lower edge of palatopharyngeal muscle and its attachment to the arching fibers of the soft palate anteriorly, through the muscle bulk itself on both pharyngeal sides. Tonsillectomy was priorly performed if needed. In 2007 Pang et al. [2] published their first paper about the modified cautery assisted palatal stiffening operation (CAPSO) consisting in the removal of a rectangular strip of mucosa from the soft palate down to the muscular layer performed under local anesthesia by means of electrocautery. The retraction due to the healing process induced the lifting of the soft palate and the widening of the posterior airway space at velopharyngeal level.

In 2009 Pang et al. published the results of their anterior palatoplasty. In this patient the soft palate was lifted and anteriorized in order to avoid the

Supplementary Information The online version contains supplementary material available at [https://doi.org/10.1007/978-3-030-96169-5_10].

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_10

anteroposterior collapse. At a 3 years follow-up evaluation the surgical success rate was as high as 86% [3].

It was only in 2012 that Mantovani et al. designed the "Roman Blinds" technique, a non-resective surgical procedure designed to shorten and stiffen the soft palate. This aim was reached by means of threads anchored to fibro-osseous attachments: the posterior nasal spine and the pterygoid hamuli [4]. The modification of this approach using self-locking threads by Salamanca et al. led to the development of the so-called barbed anterior pharyngoplasty (BAPh) [5].

In this innovative technique the rectangular-shaped excision of the mucosal and submucosal layer between the hard palate and the uvular insertion allows the significant reduction of the vibration of the soft palate, which leads to a further treatment of snoring. In the first cases, tonsillectomy was proposed only in case of large tonsils. Years by years, it has been observed that persistence of even small tonsils according to Brodsky classification [6] represented a factor of reduced anteriorization of the palate, probably related to the bulky effect of the intramuscular portion of the tonsils, so therefore tonsillectomy is now performed in all the subjects during the procedure (unless already performed).

10.1.1 Indications and Contraindications

According to Salamanca et al., BAPh should be considered effective in any case of palatal anteroposterior collapse (Fig. 10.1), with or without tonsillar involvement.

As it has already been widely stated in this book, it is necessary to identify this pattern of collapse by means of drug induced sleep endoscopy (DISE) [7]. It is fundamental to remind that no other diagnostic tools available nowadays for the evaluation of OSAHS patients (a.e. awake endoscopy with Muller maneuver, polysomnography) are as reliable and accurate as DISE in detecting sites and pattern of collapse [8, 9] even if sometimes concerns have been expressed about the

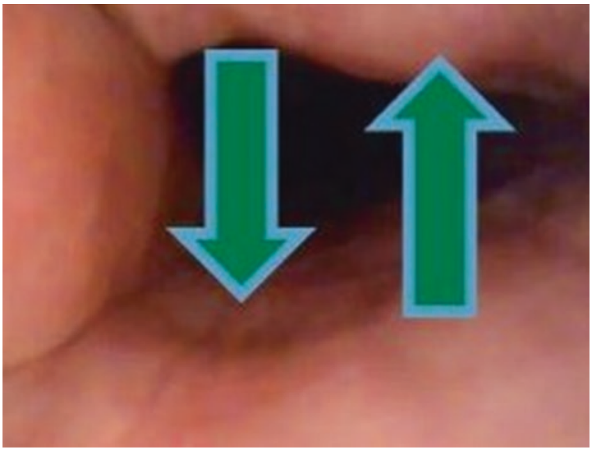

Fig. 10.1 Anteroposterior palatal collapse seen during DISE

overestimation of pharyngeal collapse as a iatrogenic effect [10]. Moreover, even if the first years palatal surgery was only considered effective in treating mild or moderate OSAHS in patients with unilevel collapse, today it has been shown to be effective in association to other surgical approaches or oral appliance in subjects with multilevel collapse (palatal, hypopharyngeal, or laryngeal) at DISE [11]. The prior indication for patients with snoring or mild OSAHS is therefore considered no more strictly valid, since it is the pattern and the level of collapse more than the severity of OSAHS to lead the surgeon to the surgical indication.

The main contraindications are represented by the presence of palatal submucosal cleft, ogival palate, palate already treated by means of radiofrequency, since this kind of surgery thins the soft palate muscular layer.

10.1.2 Surgical Technique

The procedure is performed under general anesthesia previous accurate surgical planning (Fig. 10.2).

A Davis mouth gag with cheek expander is positioned in the patient's mouth to allow the complete visualization of both hard and soft palate tonsils and tonsillar pillars, the pterygomandibular raphes, and the posterior oropharyngeal wall. The patients is then placed in Rose position. The surgeon stands behind the head of the patient. In patients not already undergone tonsillectomy, tonsillectomy is always performed independently from the grade of hypertrophy.

After chlorhexidine disinfection, identification of the following reference points by means of a dermographic pen is necessary before the surgical incision: the posterior nasal spine, the pterygoid hamuli, and pterygomandibular raphes (Fig. 10.3).

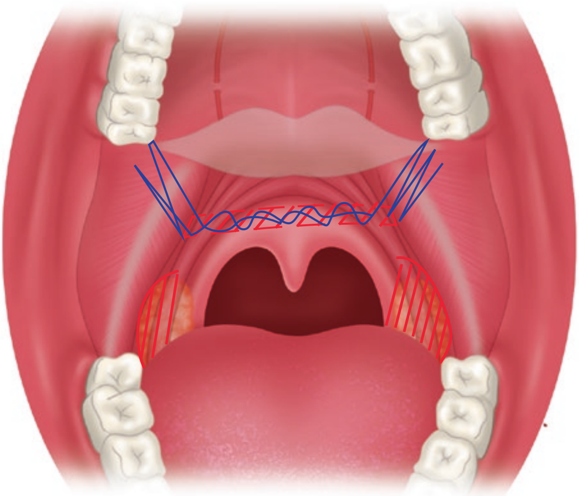

Fig. 10.2 Surgical planning: blue: palatal suture; red: tonsillectomy and palatal mucosal excision

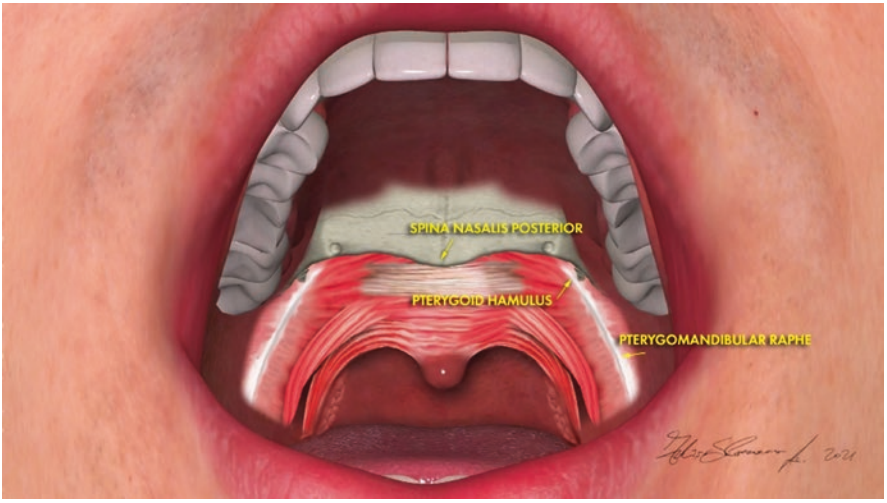

Fig. 10.3 Palatal anatomy: left spina nasalis posterior, pterygoid hamulus and pterygomandibular raphe are shown in picture

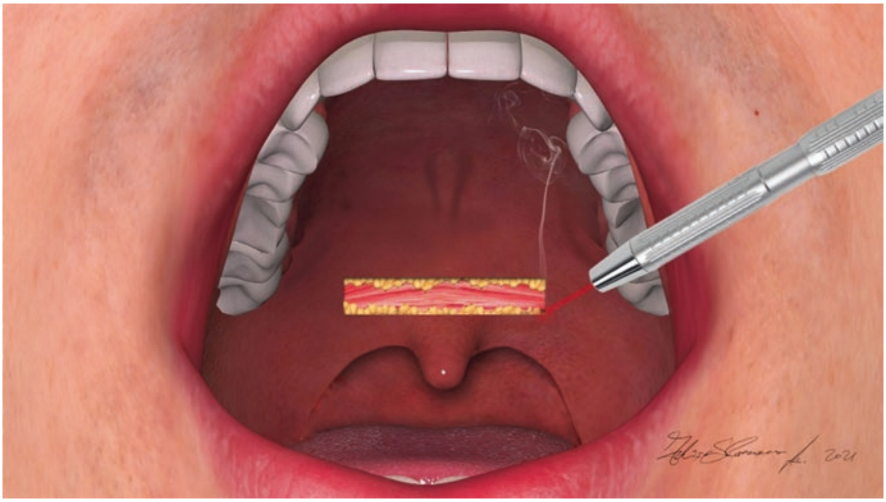

Fig. 10.4 CO_2 laser excision of the mucosal and submucosal layers

The first surgical step is represented by the dissection and removal of a mucosa and submucosal rectangular flap extending for 10–12 mm (depending on soft palate length) in the central part of the soft palate between the edge of osseous palate and the base of the uvula.

We usually perform the excision using CO_2 laser; a monopolar electric scalpel can also be used, even if the healing process is altered due to the high temperature-related effects (Fig. 10.4).

After an accurate and slight hemostasis, the muscular surface is therefore exposed. Using a spiral Polypropylene Knotless Tissue Control Device, one of the two needles enters the soft palate in correspondence of right pterygoid hamulus and exits at the level of the lower right angle of the exposed area (Fig. 10.5); the thread must be pulled out completely until the transition point blocks its progression.

The suture of the muscular layer (levator palatini, palatoglossal, and/or palato-pharyngeal muscles) is reached with a eight shaped intra-muscular continuous suture (Fig. 10.6); the thread is then passed through the muscular plane until the

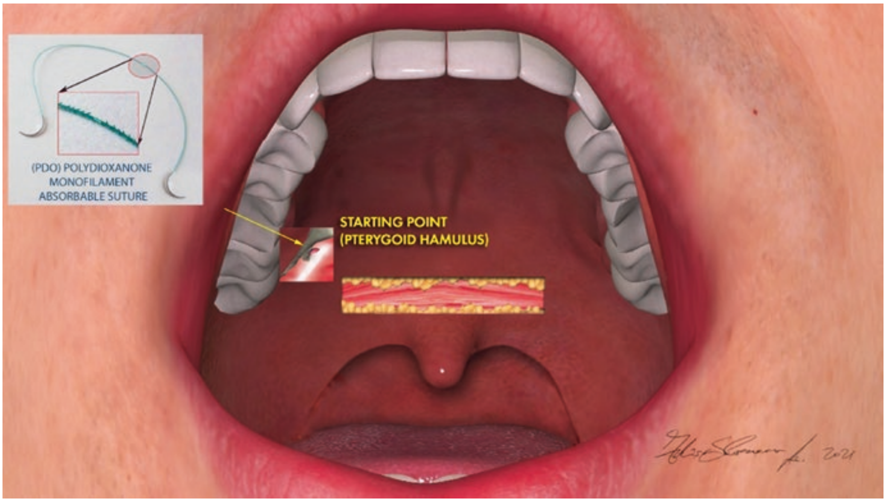

Fig. 10.5 Needle insertion at the right hamulus

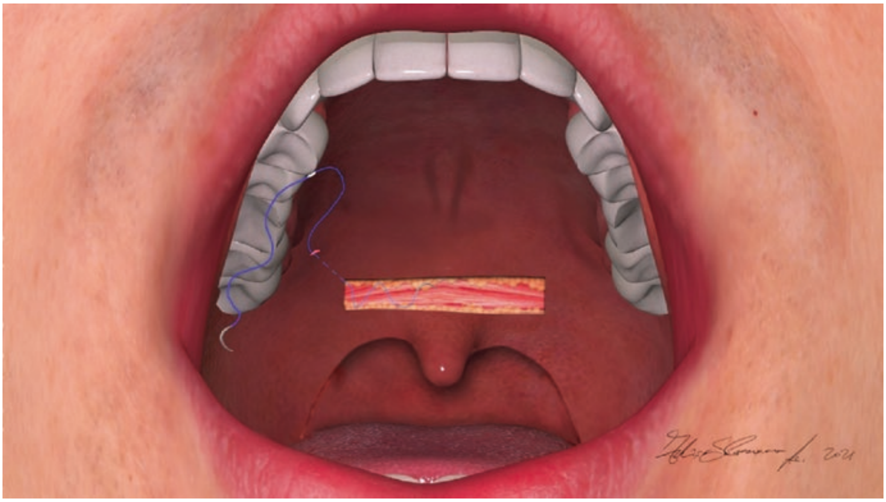

Fig. 10.6 The thread is pulled out to the transition point

closer hamulus, in order to stabilize the suture (Fig. 10.7); this side of the thread is not cut until the end of the procedure.

The other needle is used to anchor the right muscular layer to the right hamulus (Fig. 10.8), and then it runs through the submucosal layer connecting the lower edge of the wound to the palatine aponeurosis and emerges at the level of the controlateral hamulus (Fig. 10.9). The thread can now be cut at the exit point (Fig. 10.10) or on a further stitch (the so-called backstitch) running through the

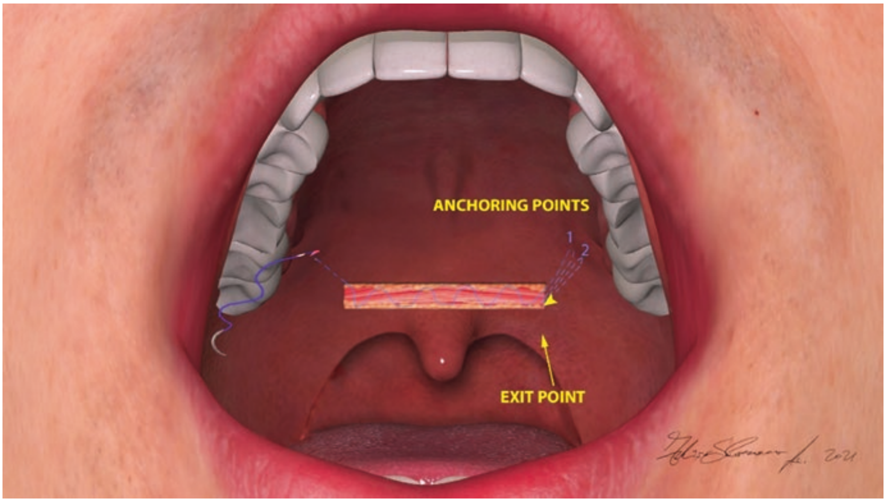

Fig. 10.7 The first thread is used to suture the muscular layer of the excision and stabilizes it at the left pterygoid hamulus

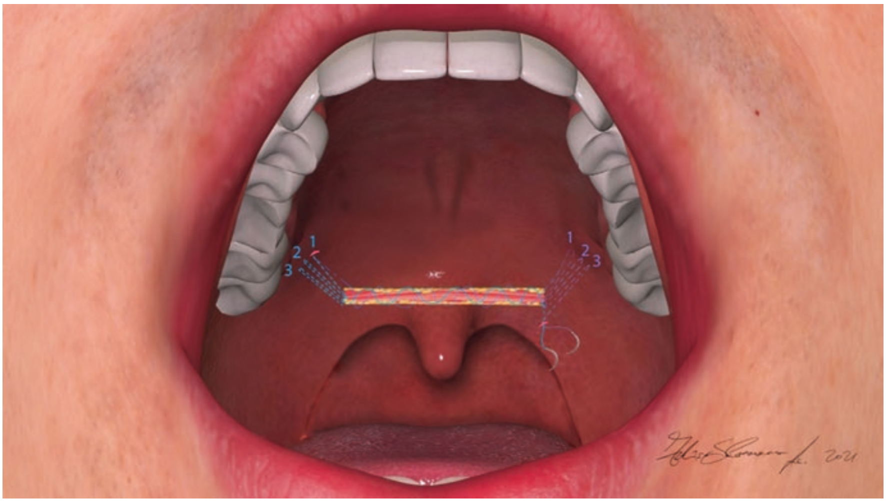

Fig. 10.8 Anchoring of the right muscular layer to the right pterygoid hamulus

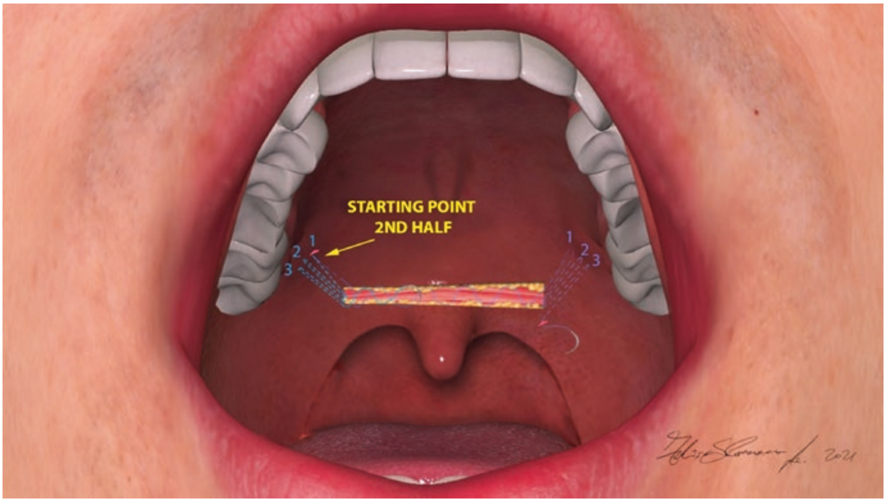

Fig. 10.9 The thread runs from the right pterygoid hamulus to the left margin of the excision running through its submucosal margins

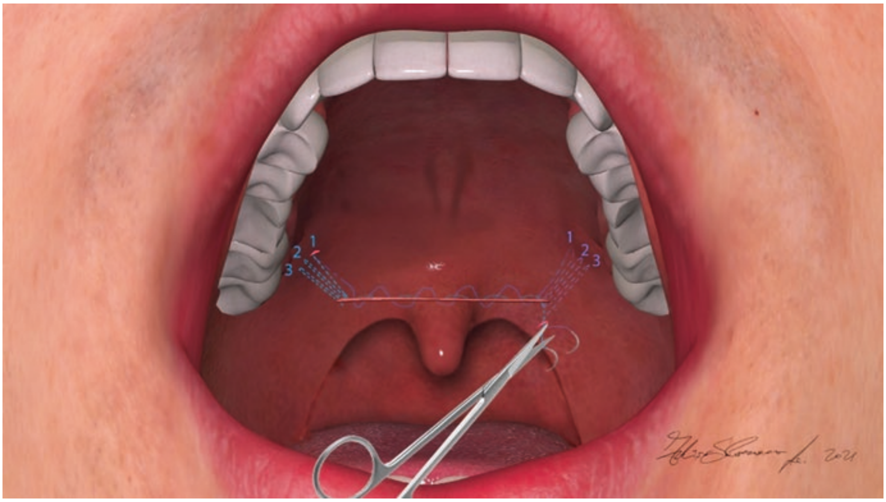

Fig. 10.10 The thread are pulled out and cut at the left end of the suture

muscular plane to the posterior nasale spine (Fig. 10.11) can be passed to furtherly stabilize the soft palate in an anteroposterior direction. The palate is now retracted, shortened, and pulled forward and the suture is tightened and stabilized (Video 10.1).

The distance between the soft palate and the posterior pharyngeal wall is increased, and the wound is closed in the near absence of visible threads (Fig. 10.12).

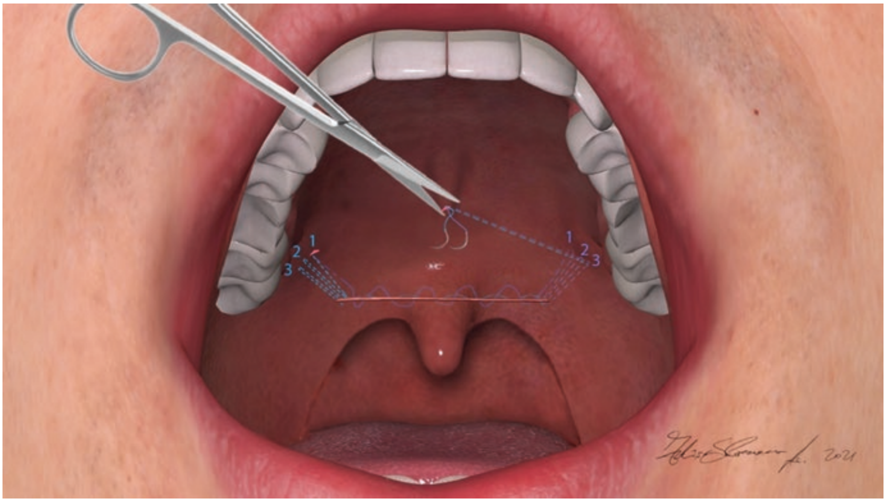

Fig. 10.11 The backstitch is cut at the posterior nasal spine

Fig. 10.12 Baph result at 24 h post op: anteroposterior palatal expansion with a little uvular edema can be appreciated. Soft palate anatomy is physiologically preserved

Healing process gives a physiological archiform shape to the operated palatal, and velar sphincteric function is intact (Fig. 10.13).

Sometimes, especially when tonsillectomy is performed, a slight medialization of the posteriors tonsillar pillars may be observed. In these patients, a small incision at the medial third of each posterior pillar (CO_2 laser is preferred for this maneuver) can be useful to decrease the muscular tension and wide the posterior pharyngeal space.

Furthermore, at the end of the procedure anterior displacement and significant edema of the uvula can be observed, with consequent hypernasal speech. Uvular edema is greater if tonsillectomy is performed. Systemic steroids administration is therefore useful in reducing this symptoms, association with smooth and cold diet

Fig. 10.13 Baph result at 12 months: a white scar can be appreciated in place of the excision, with an increase of the posterior pharyngeal space at palatal level; palatal archiform aspect is preserved

for at least 2 weeks. In order to avoid infections of the surgical sites, systemic antibiotic is needed.

As long as the palatal oedema decreases, partial thread extrusion (especially the submucosal one) can be observed; this phenomenon does not reduce the efficacy of this approach, thanks to the deeper suture running through the muscular plane. The exceeding thread should be cut at least 2 weeks after surgery, and only if ulceration of the tongue is observed.

10.2 Our Experience

Barbed anterior pharyngoplasty was first proposed in Humanitas San Pio X in Milan in 2017. Among the 247 palatal procedures carried out from 2017 to date, Baph was performed only in 23 patients. The low number of Baph in this long period is essentially due to the peculiar pattern of obstruction which has to be found at DISE. In fact, as already stated, it is indicated only if an anteroposterior palatal collapse non-responding to mandibular pull up is observed during sleep endoscopy. On the basis of our experience this phenomenon is more frequent in slender patients, especially if already undergone tonsillectomy. The analysis of our data, in fact, showed that tonsils were still present at ENT evaluation only in 31.8% of patients with palatal anteroposterior collapse at DISE. Moreover, our results showed no correlation between the severity of OSAHS or the prevalence of positional OSAHS and the indication to BAPh at DISE.

Furthermore, since the collapse at DISE in this subjects is usually multilevel, a mandibular advancement device is frequently necessary to decrease the episodes of apnea. We evaluated the efficacy of BAPh alone in patients with indication for BAPh and MAD. The mean preoperative AHI was 58.3, while the postoperative AHI (at 3 months follow-up polysomnography) was 18.3 without OA and 7.6 with MAD. We also assessed the efficacy of this procedure in treating snoring by means Snoring Visual Analogic Scale (VAS): the main preoperative VAS score was 9.2

while the 3 months follow-up score was 2.7 and 2.4, respectively, without and with MAD. While the slight difference in terms of VAS score with or without MAD is probably related to the major vibration at palatal level than hypopharyngeal or laryngeal level, the different trend in AHI reduction seems to be the consequence of more complex interacting factors.

In fact the additional improvement showed by AHI without or with MAD can be due not only to the increase of the hypopharyngeal and laryngeal posterior airways space, but also to the avoidance of the possible collapse of the tongue towards the soft palate in the mouth. This phenomenon can reduce the tension of the suture and decrease the efficacy of the surgical procedure. For this reason, if indicate, mandibular advancement devices should be applied at night as soon as possible after surgery (Videos 10.2 and 10.3).

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Barbed Lateral Pharyngoplasty

11

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11.1 Introduction

Oropharyngeal surgery for treatment of snoring and obstructive sleep apnea-hypopnea syndrome (OSAHS) went through significant changes during the last 40 years, since "partial palate resections" proposed by Quesada and Perello in 1979 [1] and "uvulopalatopharyngoplasty" devised by Fujita et al. in 1981 [2]. The main progress consisted in dropping tissue resections in favor of innovative procedures resulting from increasing awareness of palatal anatomy and function of regional muscles (see dedicated chapter in text). Surgical modifications were spurred by: (a) diagnostic advancements made possible by DISE, and consequent opportunities of appropriate case selection for each procedure, e.g. Gillespie et al. [3] and Salamanca et al. [4], and (b) knowledge of late complications of UPPP represented by: velopharyngeal insufficiency (28.5%); swallowing difficulties (24.4%); dry throat (22.4%); foreign body sensation (20.4%); and speech disturbances (16.3%), e.g. in the retrospective analysis of Goh et al. [5]. Consequently, about 50 different palate surgery techniques have been described in the literature over the last 20 years, among which the following deserve a mention since they deal with oropharyngeal lateral walls:

Supplementary Information The online version contains supplementary material available at [https://doi.org/10.1007/978-3-030-96169-5_11].

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_11

(1) **Lateral pharyngoplasty (LP)** first described by Cahali in 2003 [6] with the purpose to weaken superior constrictor and palatopharyngeus muscles whose action closes the pharynx; (2) **Expansion sphincter pharyngoplasty (ESP)** devised by Pang and Woodson in 2007 [7] in the search of a simple and quicker technique to get a useful "pharynx opening" action through the upward and lateral rotation of palatopharyngeus muscle; (3) **Relocation pharyngoplasty (RP)** suggested by Li and Lee in 2009 [8] in which the palatopharyngeal muscle is dissected from the superior pharyngeal constrictor and paralyzed with sutures; (4) **Functional expansion pharyngoplasty (FEP)** described by Sorrenti and Piccin in 2013 [9] who realized the supero-lateral repositioning of the palatopharyngeus muscle through a tunnel under the mucosa, a less aggressive and more physiologic approach; (5) **other Modified ESP techniques** appeared in 2013 from McKay et al. [10] and in 2014 from Vicini et al. [11]; (6) **Anterolateral advancement pharyngoplasty (AAP)** by Emara et al. in 2016 [12] in which the muscular fasciculus of the anterior part of the palatopharyngeus muscle is carefully dissected and then elevated and advanced, fixing it to the pterygomandibular raphe, while the posterior part of the palatopharyngeus muscle is fixed superolaterally behind the palatoglossus muscle. Hints and suggestions from all the cited procedures have been remembered and valued when designing **Barbed Lateral Pharyngoplasty (BLph)**, together with the awareness of the opportunities offered by the use of the barbed threads and the concepts of barbed snore surgery (see dedicated chapters in text).

11.2 Material and Methods

11.2.1 Equipment

Surgical equipment consists in the usual set of instruments adopted for palatoplasties (i.e. mouth gag, bipolar Molecular Quantum Resonance forceps, surgical forceps, needle holder, and scissors), CO_2 laser device, and barbed threads.

Magnification of the surgical field is generally unnecessary.

Two types of barbed threads have been used (with slightly different techniques):

1. the "V-lock" PDO absorbable "2-0" monodirectional thread, with a 1/2 circle 27 mm atraumatic needle on one side and a terminal loop on the other side;
2. the "Stratafix" PDO absorbable "0" bidirectional thread (24 + 24 cm) with a 1/2 circle 36 mm atraumatic needle at each extremity and a barb direction transition point in the middle.

11.2.2 Principles

The basic principle of barbed lateral pharyngoplasty is to apply an outward vector to the lateral walls of the oropharyngeal sphincter in those cases that reveal a lateral collapse or vibration pattern during sleep endoscopy (DISE) (Fig. 11.1).

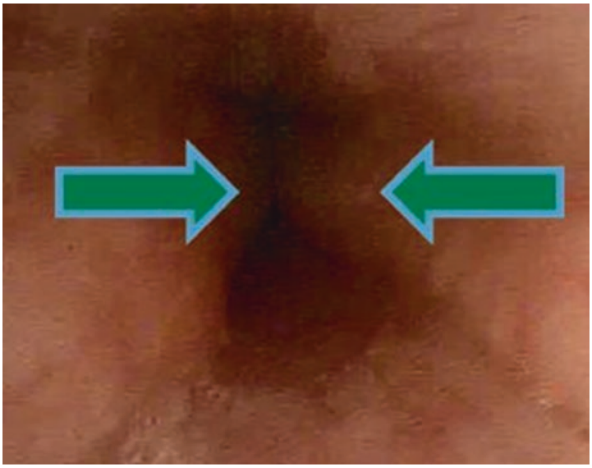

Fig. 11.1 Lateral collapse during DISE

Therefore sleep endoscopy is the fundamental pre-operative examination to choose the appropriate surgical technique for each individual patient (Video 11.1).

This type of pharyngoplasty may be performed with both unidirectional single needle and bidirectional double needle self-locking threads. Opening of the oropharyngeal sphincter is obtained by engaging muscular and mucous tissues of the oropharynx bringing them laterally towards the pterygomandibular raphe (one of the stable structures closest to the operative region), with two or more passages of the barbed thread, depending on the case, as detailed in the surgical technique.

The barbed surgical technique to which we refer, in this case, is the barbed functional expansion pharyngoplasty by Sorrenti et al. [13].

11.2.3 Indications and Contraindications

Barbed lateral pharyngoplasty is indicated in lateral endoscopic velopharyngeal/oropharynx patterns of obstruction and snoring.

However, this technique also finds a good indication in circular patterns, especially in cases where the application of an oral device is also envisaged in therapeutic planning.

Consequently, one more time we stress that the lack of a DISE study is the first fault in the making of this surgery. If tonsils are present, tonsillectomy is always required.

This surgical technique may be part of a multilevel surgical approach when, for example, there is a constriction at the tongue base or at the epiglottis level.

At times we also use Barbed Lateral Pharyngoplasty in cases where a previous surgery did not achieve satisfactory results, or even worsened the situation, with a “gothic dome” closure of the pharynx.

Significantly obese Patients (BMI $\geq$ 35) are not candidates to surgery and such statement also applies to BLPh.

11.2.4 Surgical Planning

Before surgery, the surgical planning is defined with a drawing on the paper (Figs. 11.2 and 11.3).

11.2.5 Surgical Technique

Surgery is conducted under general anesthesia with oral-tracheal intubation.

The surgeon sits at the top of the table, with the patient's neck hyper-extended to fully expose the posterior palate; McIvor mouth gag is positioned. First of all the surgical field is disinfected with chlorhexidine.

The first step in our procedure is to mark reference points with a dermographic pen: the end point of bony palate on the midline (the posterior nasal spine), the relief of pterygoid hamulus and pterygomandibular raphe on both sides. Often, however, we mark these landmarks with a small scarification of the overlying mucosa, using a low-power electric monopolar with a fine tip, or a CO_2 laser spot; we use such devices in cases of abundant salivary secretion which may alter the drawings of the dermographic pen, diluting, and expanding them. Tonsillectomy is usually the first surgical step of the technique (Fig. 11.4): we perform tonsillectomy with multiple radiofrequency bipolar forceps: Molecular Quantum Resonance.

It allows a bloodless removal of the palatine tonsil without overheating the nearby muscle tissue (58–60 °C), especially the palatopharyngeal muscle, thus ensuring a vital muscle flap without irreversible damage: paying attention to this topic will allow good stability and sealing of the suture.

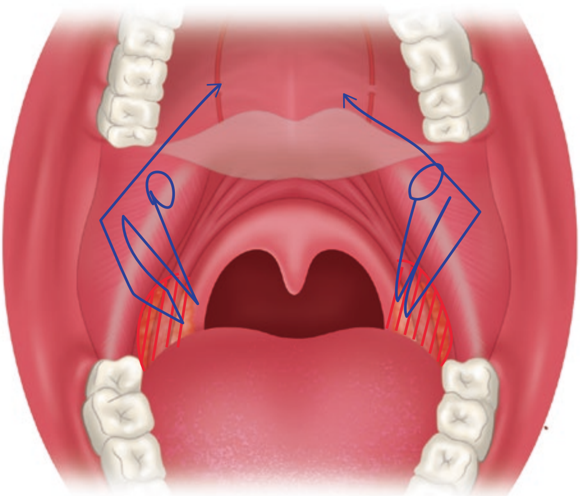

Fig. 11.2 Surgical planning with monodirectional thread

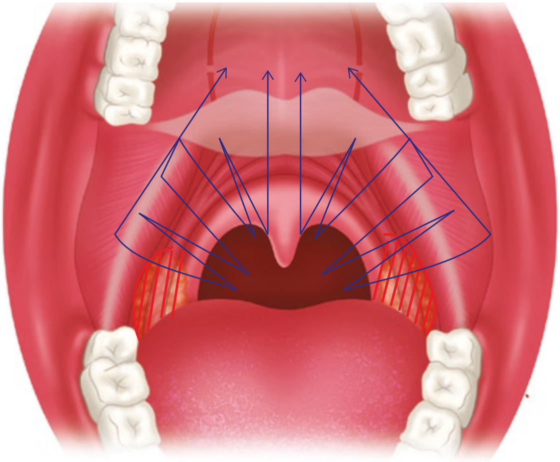

Fig. 11.3 Surgical planning with bidirectional thread

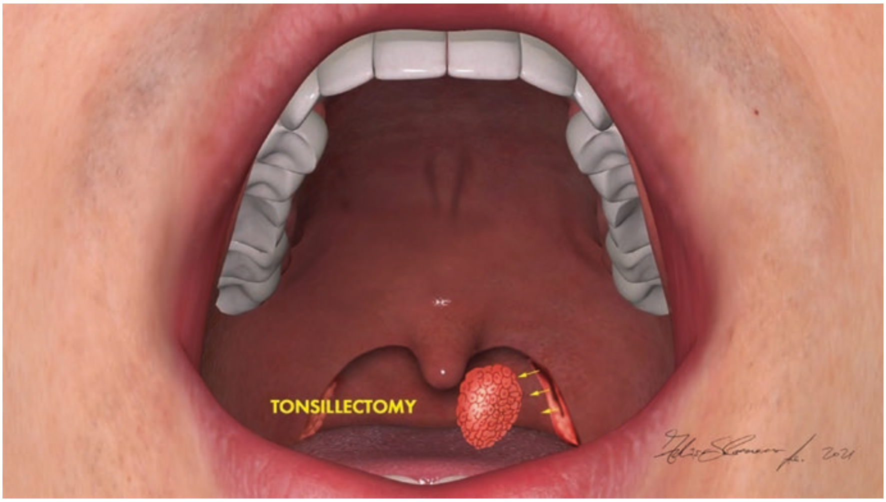

Fig. 11.4 Tonsillectomy is the first surgical step

In fact, if we engage with the self-locking threads a muscle flap bound to necrosis within a few days, the tightness of the entire suture will be compromised.

The second surgical step of BLPh is the preparation of the palatopharyngeus muscle flap. We create a supero-medial hinged flap of 2/3 of the medial bundle of the palatopharyngeus muscle which constitutes the posterior wall of the tonsillar loggia. In making the flap we often use the CO_2 laser: in this case the precision of CO_2 laser is counterbalanced by larger heating of tissues during the section; we must therefore take into account that about 1–2 mm of the flap may get necrotic.

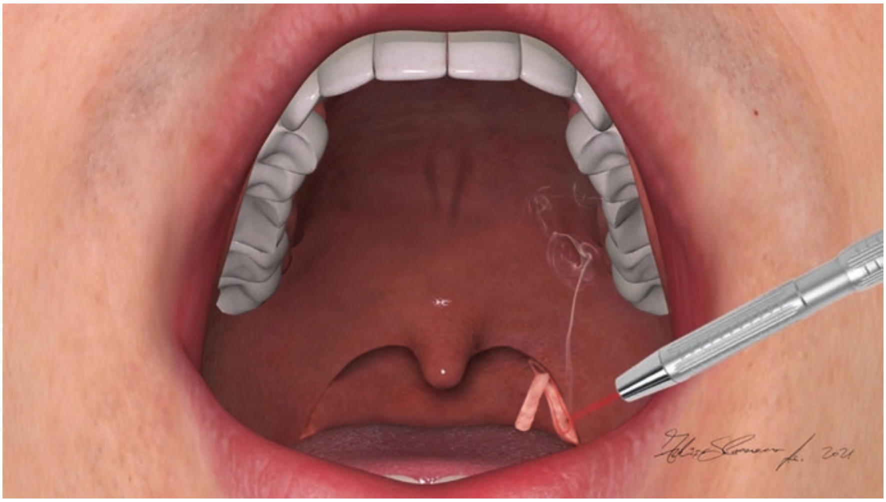

Fig. 11.5 Preparation of palatopharyngeal muscle flap

The muscular flap must be full thickness, with a good top hinged base. This base is the engagement area of the barbed suture. Preparing the flap we also dissect the mucosa so that a muscular-mucous flap is formed and important mucosal tensions don’t exist at the time of lateral engagement of the flap.

Even in the case of surgical techniques with self-locking threads, our experience tells us to avoid areas of significant tension in the operating area as much as possible: the muscle flaps could tear apart, thus nullifying the expansion vectors (Fig. 11.5).

At this point the central and final surgical step of this technique begins: the suture with self-locking threads.

Sometimes we use unidirectional threads with eyelet and single needle (e.g. V-Loc) and in other cases bidirectional threads with double needle (e.g. Stratafix).

The arrangement of the barbs is still spiral around the thread, but the shape of the barbs changes.

In unidirectional threads the barbs are built with a double cutting angle, thus creating thick but not very deep barbs in the thickness of the wire.

In bidirectional ones, the barbs are set up with a single acute cutting angle which makes the barbs sharper, less thick, but deeper in the thickness of the thread. We tend to favor V-Loc in BLPh except in cases with significant thickness of the palate and palatopharyngeus muscle in which we prefer to place more barbs for tissue engagement. Let us begin describing the technique with unidirectional wire (Figs. 11.6 and 11.7).

The suture begins at the supero-medial third of the pterygomandibular raphe: it enters from the outside to the inside under the raphe, full thickness, and the thread is pulled up to the stop with the buttonhole, the needle is passed through the eyelet and thus a kind of *noose* is formed that wraps the whole raphe: this is the sealing

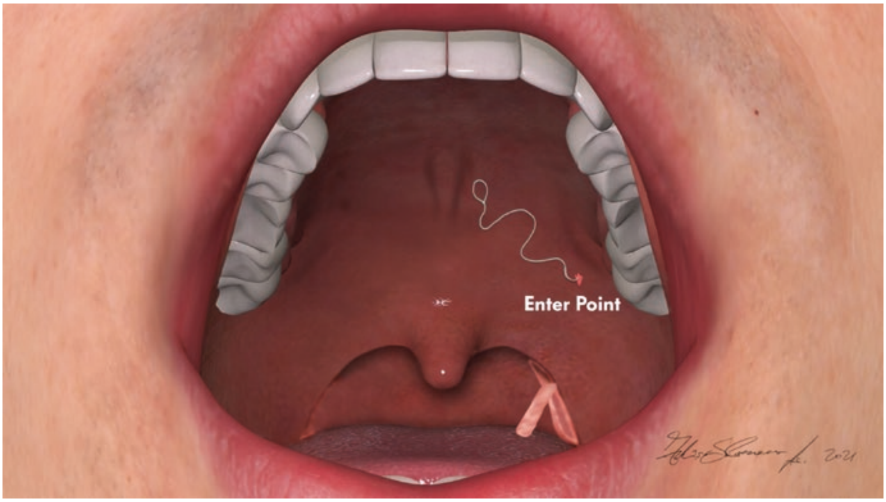

Fig. 11.6 Needle is inserted cranial to pterygomandibular raphe

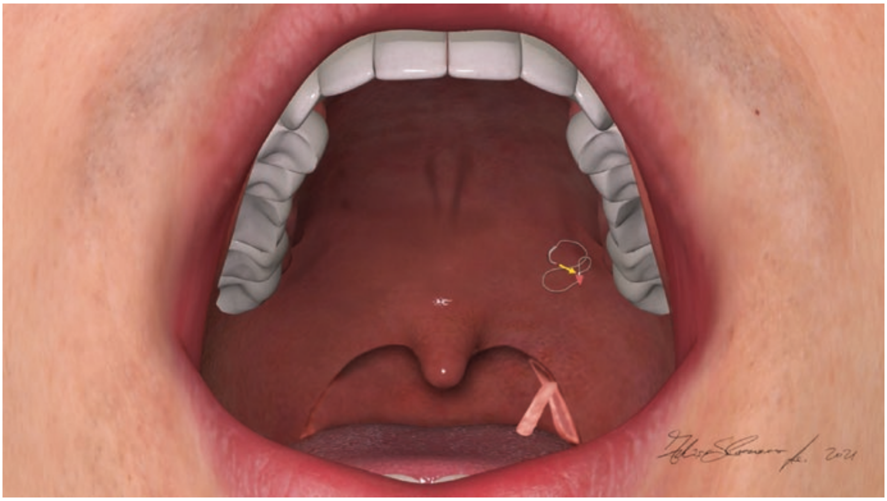

Fig. 11.7 Needle gets through the loop and enters again the mucosa

point of the whole suture. The needle then enters deeply under the raphe into the muscular plane, directing the suture towards the loggia to engage the muscle-mucous flap of the palate-pharyngeus. If the soft palate is particularly long, it will be necessary to make 1 or 2 passes with the needle to get to the loggia, exiting the palate mucosa and re-entering at the same point, thus creating a "quilting" that isn't absolutely a mistake, rather gives strength to the suture. At the level of the loggia, the entire base of the flap is wrapped, then we take it back in full, and pull the wire

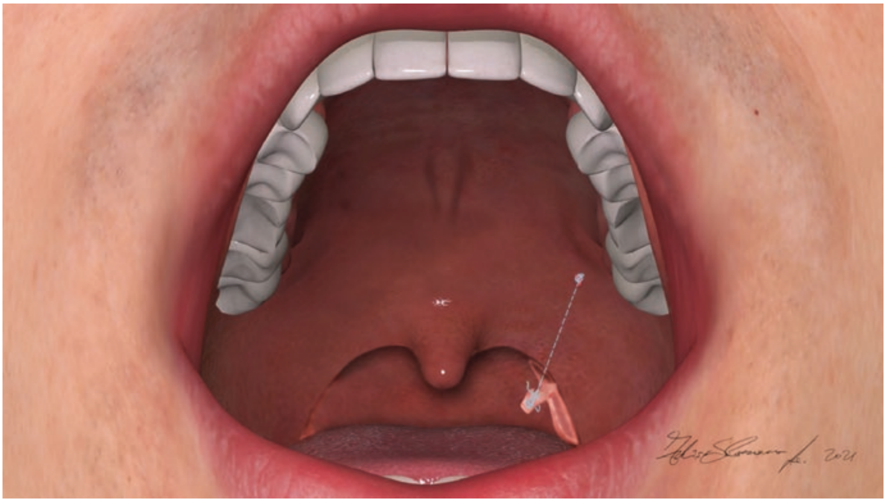

Fig. 11.8 Needle engages muscular flap by passing through it two or three times

to "entangle" it to better engage the flap: so the flap is not only engaged by the beards but also by the crossing of the thread (Fig. 11.8).

At this point we return deeply towards the supero-medial third of the raphe, all in covered way. Once out of the raphe, the actual engagement of the tissues and the flap is practiced and the entire lateral wall of the oropharynx may be seen moving laterally and repositioning further forward. At least once again, the grip of the flap and the lateral engagement are repeated (in some cases, several passes are carried out until a good lateral expansion is obtained): the important topic is to avoid to make the suture too close to the dental arch owing to the proximity of the lingual nerve (Fig. 11.9).

Let us now consider bidirectional thread technique.

When "Stratafix" suture thread is used, the thread is turned around the pterygomandibular raphe to encircle it at 360° before the beginning of the suture of the flap. Compared to the previously illustrated technique with V-loc suture threads, it differs in the fact that the suture begins by inserting the thread at the level of the pterygomandibular raphe up to the region of inversion of the beards (region without beards) and by making a loop around the raphe. The thread is passed from the outside to the inside and under the raphe with the needle, then it is pulled up to the stop (for the start of the contralateral beards) and re-entered under the raphe, always from the outside to the inside thus wrapping the whole raphe with the part of the wire without beards. The suture continues in the same way as in the previous technique, with the only difference that the flap is entered at its base by both threads separately. The wires are not "tangled" and then both wires are brought sideways and "engaged" at the same time: here too we will see a good lateral and anterior expansion. It is clear that in this technique, since there are two threads in place, there will be more beards in place, albeit thinner (Fig. 11.10).

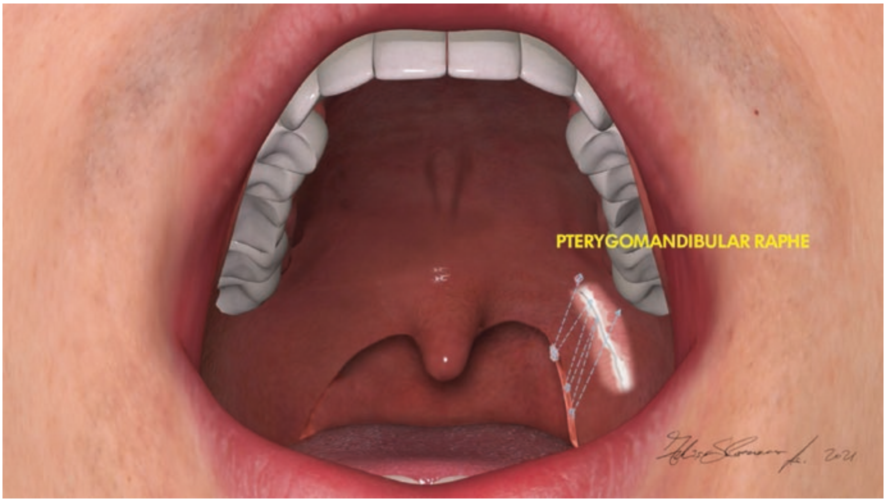

Fig. 11.9 Lateral expansion is obtained with multiple passages between palatopharyngeal muscle and pterygomandibular raphe

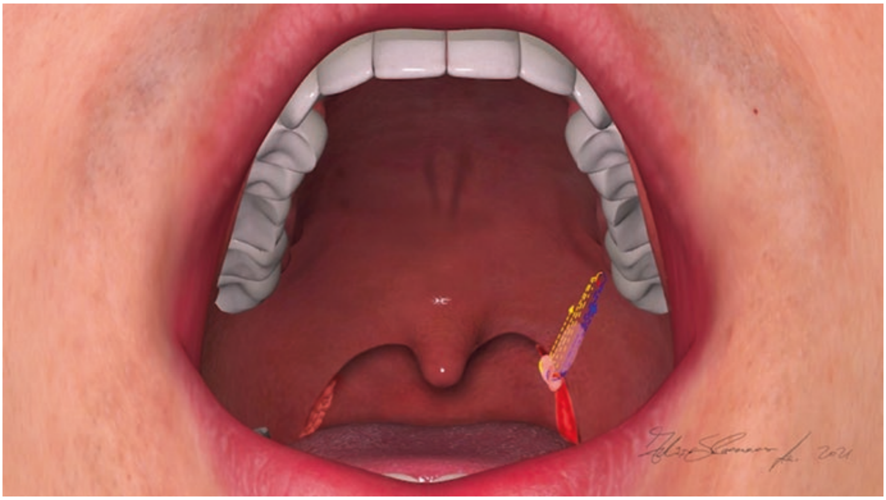

Fig. 11.10 Thread is turned around pterygomandibular raphe to encircle it at 360°, than, palatal-pharyngeal flap is entered at its base by both threads separately

In both techniques the last step of the suture concerns the so-called stabilization backstitch: that is, we try to house the end of the thread with its beards, before its final cut, in a more stable and more consistent area (palatine aponeurosis) and make last engagement of tissues: further lateralization of the pharyngeal wall and a settling and compaction of the entire suture will be seen.

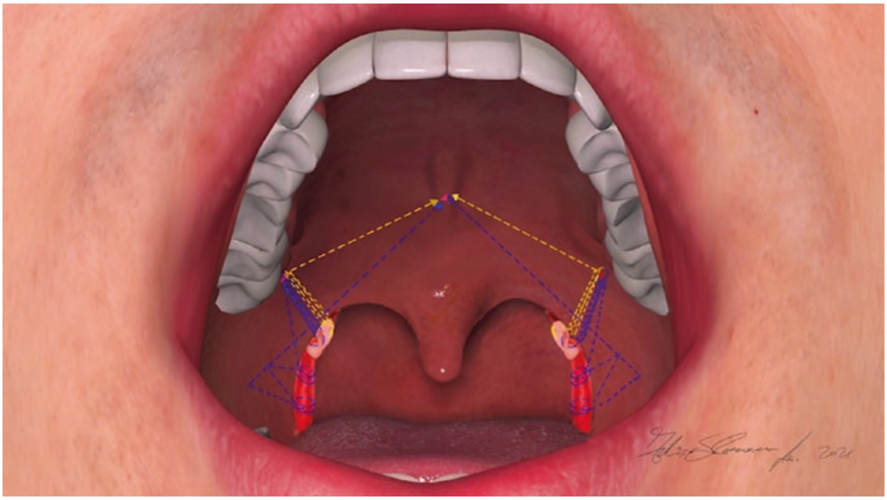

Fig. 11.11 The backstitch

Small variation: using the bidirectional self-locking wire if, in addition to a good lateral expansion, we also want to further advance a particularly thick and flaccid soft palate, after engaging the muscle flap of the palatopharyngeus with the two wires, we can use one part of the thread for lateral expansion and the other to bring the soft palate further forward (Fig. 11.11).

We do not place sutures in the lower 1/3 of the tonsillar fossa, since in our experience it makes easier to treat incidental post-tonsillectomy bleedings. Obviously, after shaping the pharyngeal lateral wall on one side we switch to the other side. Finally, if we need to perform uvulotomy, we usually do it with CO_2 laser at its distal third without ever removing the whole adipose body of the uvula in order to be sure to safeguard the azygos muscles bilaterally. If any doubts exist about the results of the intervention, an endoscopic examination may be performed before the awakening of the patient. We can perform this check either directly with a flexible fiberscope or indirectly using a laryngeal mirror, coated with anti-fog or heated: it is important to check the amount of lateral expansion of the oropharyngeal sphincter (Video 11.2).

At the end of the procedure, in some cases the tension of the soft palate may seem excessive, but it must be taken into account that in the following days this tension gradually loosens; in any case, no patient in our case group had a soft palate insufficiency (Videos 11.3, 11.4, 11.5, and 11.6).

11.2.6 Post-operative Care

Operated patients are controlled daily by the surgeon and dismissed on the first or second post-op day, with following weekly appointments, for about 1 month (Figs. 11.12, 11.13, 11.14, and 11.15). On the last post-op visit a video-endoscopic

Fig. 11.12 First post-op day: BLPh with monodirectional thread

Fig. 11.13 First post-op day: BPLh with bidirectional thread

Fig. 11.14 Four months after surgery

evaluation is recorded (Fig. 11.16) and a satisfaction form is filled in by the subject and her (his) bed partner. Follow-up control is then scheduled after 6 months with post-op poligraphic results. We did not observe major complications after BLPh surgery.

Post-operative pain, mostly relative to tonsillectomy, lasted an average of 10–12 days, and post-operative medical treatment involved the administration of antibiotic therapy and low-dose steroid therapy for about 10 days; paracetamol was used for analgesia; anti platelet-aggregation drugs were avoided.

Fig. 11.15 Two years after surgery

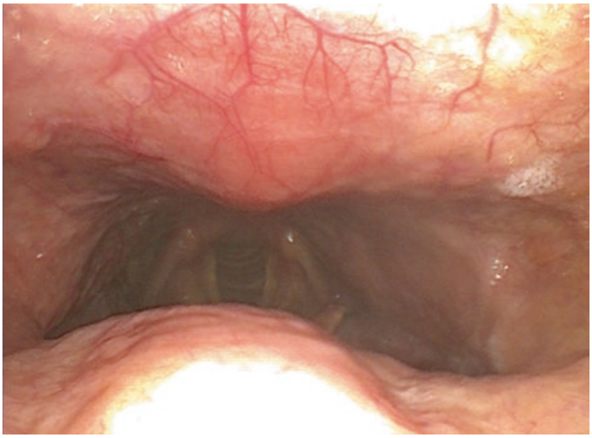

Fig. 11.16 Video-endoscopic evaluation 2 months after surgery: lateral expansion of the oropharyngeal sphincter

Patients followed a controlled diet by eating soft and cold foods for 10–15 days.

The use of barbed sutures involves sometimes the need to remove externalized portions of the thread in the days following surgery, mostly when edema of the soft palate decreases. Extramucosal threads (primarily the ones causing lesions of the tongue and painful deglutition) should be removed, but it is better to wait at least 15 days after the operation. Externalization of a thread in the first days after surgery may be caused by too superficial passages within the suture, that make it ineffective.

In our experience the removal of part of the thread doesn't impair the effectiveness of surgery, because the scarring induced by the suture still has a sealing effect.

It may also happen that in the days following surgery the muscular flap of the palatopharyngeus muscle loses its hold, because it has been badly hooked or because it is too thin: this does not lead to a bad final result, but the soft palate may heal in an asymmetrical way.

11.3 Outcomes from the Literature and Personal Experience

Reporting outcomes of pharyngeal surgery studies published in the literature from the point of view of polysomnographic results is complicated by the use of different criteria to evaluate results in earlier papers; only after about year 2009 the widespread use of criteria proposed by Sher et al. [14] for "success" and "cure" allowed comparisons of case groups and techniques. We notice that when selective pharyngeal surgery is applied, e.g. non-resective procedures like Lateral Pharyngoplasty (LP) success rates are between 70% by Carrasco et al. [15] and 100% by Dizdar et al. [16]. Other surgical approaches dealing with lateral pharyngeal walls display good success rates, e.g. Expansion Sphincter Pharyngoplasty (ESP) with 82.6% in Pang and Woodson's study [7] and 90% in Carrasco et al. case group [15], and Functional Expansion Sphincter Pharyngoplasty (FESP) by Sorrenti and Piccin [9] with 89.2% success rate. The use of barbed surgery techniques to approach lateral pharyngeal walls has proved to be very effective in several papers: Barbed Reposition Pharyngoplasty (BRP) got 90% success rate in the hands of Vicini et al. [17] and 93% in the hands of Barbieri et al. and Barbed Suspension Pharyngoplasty got 100% success rate and 40% cure rate by Barbieri et al. [18].

From January 2017 to December 2020 we performed the intervention of Barbed Lateral Pharyngoplasty described above on a group of 134 subjects: 116 OSAHS cases and 18 Habitual Snoring cases. We operated 52 severe, 34 moderate, and 30 mild OSAHS cases. Every patient underwent sleep endoscopy before surgery to disclose the individual pattern of vibration and obstruction. Post-op AHI values demonstrated that OSAHS condition was "cured" by the operation (as defined by Sher et al. [14]) in all mild and moderate OSAHS cases and 49 out of 52 severe OSAHS cases. This means a positive result in 113 out of 116 OSAHS patients submitted to BLPh (97%). It must be considered that our full therapy prescription involves in many cases the application of a MAD (Mandibular Advancement Device), according to sleep endoscopy indications, and therefore post-op polysomnography is often performed with an oral appliance in site.

11.4 Conclusions

Barbed lateral pharyngoplasty, in our experience, is very effective in the treatment of snoring and obstruction of the oropharyngeal lumen with a lateral and circular pattern.

It is frequently performed in multilevel surgery (associated with epiglottis or robotic surgery—TORS), but for many years we did not associate it with major nasal surgery (septoplasty or FESS) which requires bilateral tamponade. In fact, especially when we also perform uvulotomy, a significant edema of the uvula may frequently arise, which may create oral breathing difficulties; for this reason we prefer not to associate a nasal respiratory obstruction, even if temporary.

If the patient is already under CPAP (Continuous Positive Air Pressure) therapy before surgery and we perform the operation to try to wean the patient from ventilatory therapy, we keep CPAP therapy in the post-operative period, that supports good breathing even in the presence of soft tissue edema.

In addition, the use of CPAP in the post-operative period, if indicated, reduces recovery and normalization times of pharyngeal tissues.

If our full therapeutic planning also includes the use of a MAD (Mandibular Advancement Device), we ask the patient, if possible, to obtain it before the intervention and then apply it in the post-operative period to prevent a fall of the tongue over the operated region, especially in the supine position.

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Circular Pharyngoplasties

12

Alessandro Bianchi, Vittorio Rinaldi, Federico Leone, Fabrizio Salamanca, and Lorenzo Pignataro

12.1 Alianza Technique

The pharyngoplasty called Alianza was conceived and developed by Professor Mario Mantovani in 2014 [1].

The idea is to counteract the circular collapse of the velopharyngeal soft tissues observed during sleep endoscopy (DISE) when the obstructive pattern is circular (Fig. 12.1, Video 12.1).

Sleep endoscopy is therefore the fundamental pre-operative examination for choosing the most appropriate surgical technique for each individual OSA patient [2–4].

According to the findings of sleep endoscopy, it is a question of joining the antero-posterior vectors with the lateral vectors to create a circular vector [5].

Supplementary Information The online version contains supplementary material available at [https://doi.org/10.1007/978-3-030-96169-5_12].

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_12

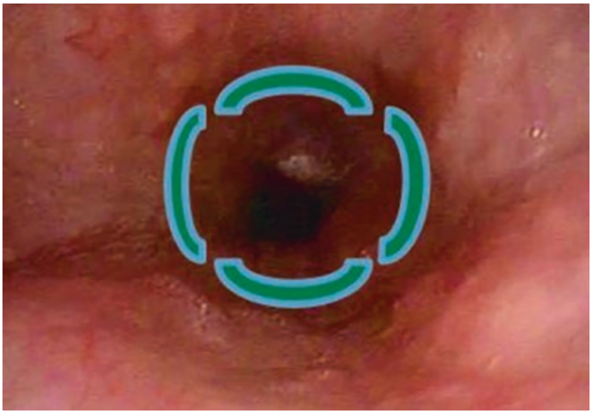


Fig. 12.1 Circular velopharyngeal pattern during DISE

To do this, Mario Mantovani decided to combine Anterior Pharyngoplasty (BAPh) [6] and the Barbed Roman Blinds Technique (BRBT) [7, 8] in a single operation: the goal of the Alianza technique is to create a ring suture with circular vectors.

In Spanish the wedding ring is called Alianza, hence the name of the technique.

In this intervention the principles of Barbed Snore Surgery (BSS) are respected: (1) the use of the barbed sutures; (2) muscular preservation; (3) the use of "as many as possible" safe anatomic holds (posterior nasal spine, pterygoid hamulus, palatine aponeurosis, pterygomandibular raphe); (4) Custom-made surgery according to DISE features (circular velopharyngeal collapse).

12.2 Indications and Contraindications

Alianza surgery is indicated in circular endoscopic velopharyngeal patterns of obstruction and snoring, possibly associated with a thick and ptosis uvulopalatal complex, in patients with OSAS and simple snoring.

It is therefore clear that, before choosing this technique, a sleep endoscopy is required to confirm the type of obstruction and snoring pattern. If tonsils are present, tonsillectomy is always required.

This surgical technique can be part of a multilevel surgical approach when, for example, there is a problem at the tongue base or at the epiglottis.

When a velopharyngeal surgical technique has already been performed, this intervention is generally contraindicated; in selected cases, Alianza technique can be repeated in case of relapse of velopharyngeal collapse or vibration and can be proposed in case of failure of a previous unsuccessful remodeling velopharyngeal surgical technique, such as BRBT or BRP.

12.3 Surgical Technique

Surgery is conducted under general anesthesia with trans oral-tracheal intubation.

The surgeon sits at the top of the table with the patient's neck hyper-extended, the palatopharyngeal structures are exposed with a mouth gag (Mc-Ivor, Dingman or Davis).

A rigid nasal endoscope (0°, 45° or 70°) or an exoscope (Stor2D or 3D) connected to a high definition and resolution video stack/camera should be used to document the surgery, with the screen positioned at the side of the patient's legs. We consider extremely important and useful to document and record the surgery both for teaching purposes and to facilitate the postoperative analysis of successes and failures of our surgical treatment; moreover it is important to allow the nursing staff to actively participate in the intervention, because the limited surgical oropharyngeal workspace otherwise makes it impossible to follow the surgery. The surgical microscope can represent a valid option to document the surgery: it offer a brilliant resolution of the details but sometimes an unsatisfactory overview of the operating field with the frequent need to reposition the microscope.

We routinely mark with ink the oral mucosa over the surgical landmarks: the end point of osseous palate on the midline (the posterior nasal spine), the relief of pterygoid hamulus and pterygomandibular raphe of both sides.

Tonsillectomy is performed if tonsils are present; in case of previous tonsillectomy it is necessary to perform tonsillar fossa mucosectomy in order to expose the palatopharyngeal muscles and to facilitate the next surgical steps.

The first steps of this surgical technique are the same of the barbed anterior pharyngoplasty (BAPH). The mucosal palatal flap is dissected and removed, preferably performed using radiofrequency or coblation electronic devices (operating at low temperatures) in order to speed wound recovery and reduce postoperative pain [9]. This flap consists of a semilunar portion of palatal mucosa, not rectangular like in BAPH technique; the excision area extends for 10–12 mm (depending on soft palate length) in the central part of the soft palate between the edge of osseous palate and the uvula attachment (Fig. 12.2).

When removing the mucosal strip, it is quite important to remove also the submucosal layer, containing fat and minor salivary glands, in order to expose the underlying muscular surface. Hemostasis is performed using bipolar cautery forceps or coblator.

We use the PDO barbed bidirectional thread 0, 2.0, or 3.0 (in the 24 × 24 cm, 36 × 36 cm, or 40 × 40 cm configuration on taper-pointed 36 or 26 mm semicircular needles). The thread has a barb-free portion in the middle representing the barb direction transition point; the two halves of the thread, with an opposite direction of barbs, can be used to perform the procedure in the two sides of the surgical fields.

The first step of Alianza technique consists in creating a central pivotal loop at the level of the posterior nasal spine using the middle of the barb-free length portion of the thread.

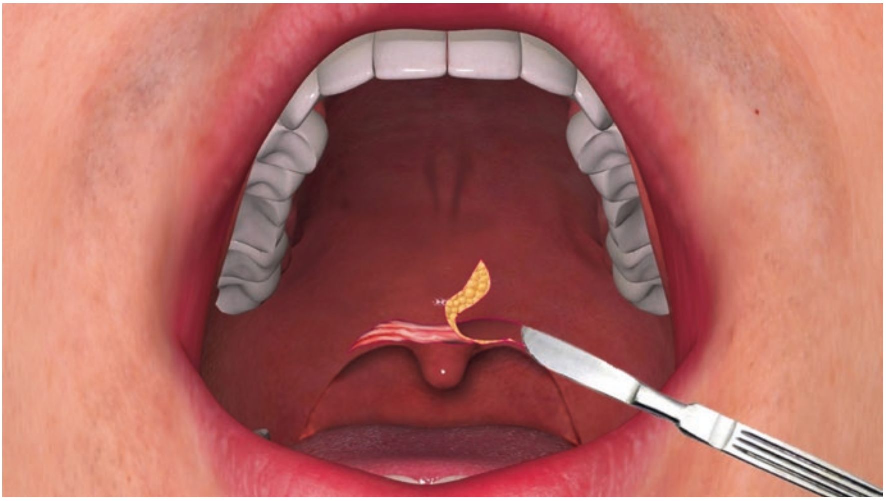


Fig. 12.2 Removal of mucosal strip with minor salivary glands to expose muscular surface

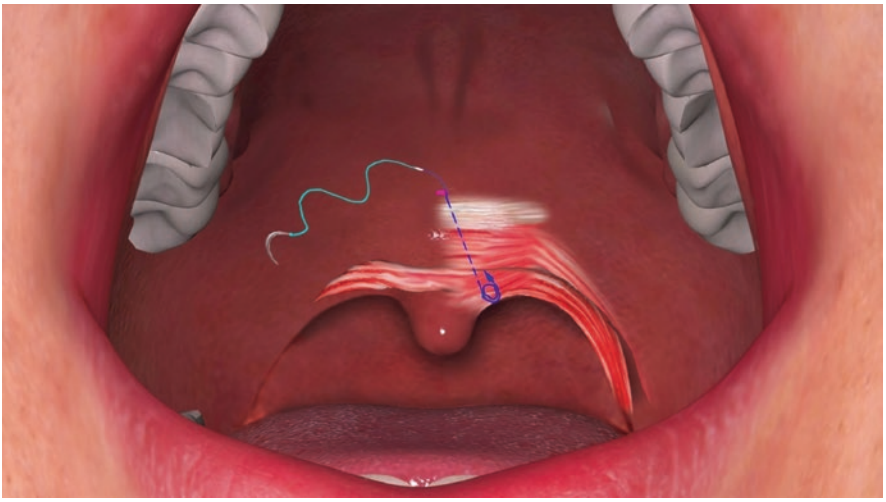


Fig. 12.3 Suture starts at posterior nasal spine; the suture needs to hook the muscle layer (horizontal fibers of the palatopharyngeal muscle) once or twice from back to front

The first needle is inserted at the level of the posterior nasal spine through the periosteum and the fibromuscular layer of the soft palate, driven downwards (in one or more passages) at the level of inferior part of the flap until it perforates the mucosa adjacent to the ipsilateral base of the uvula. It is then reinserted through the same mucosal hole thus encircling once or twice the upper part of the palatopharyngeal muscle (Fig. 12.3).

In the next step the needle is the driven upwards (in one or passages) in order to reach the palatine aponeurosis (Fig. 12.4).

We repeat this step one or two more time, but slightly more to the side; then we drive our needle sideways to engage the fibro-periosteal tissues around the pterygoid hamulus. At the end of these steps we obtain the closure of the anterior palatal wound (Fig. 12.5).

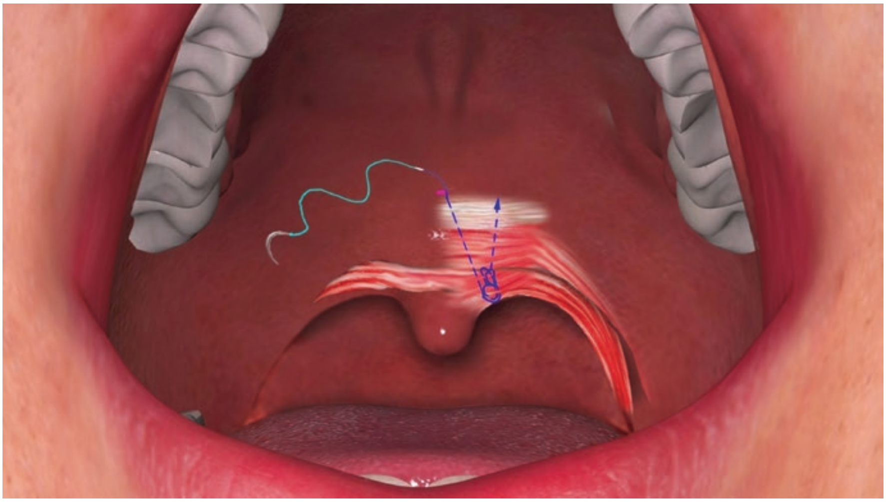


Fig. 12.4 The thread starts suspending the soft palate to the palatine aponeurosis

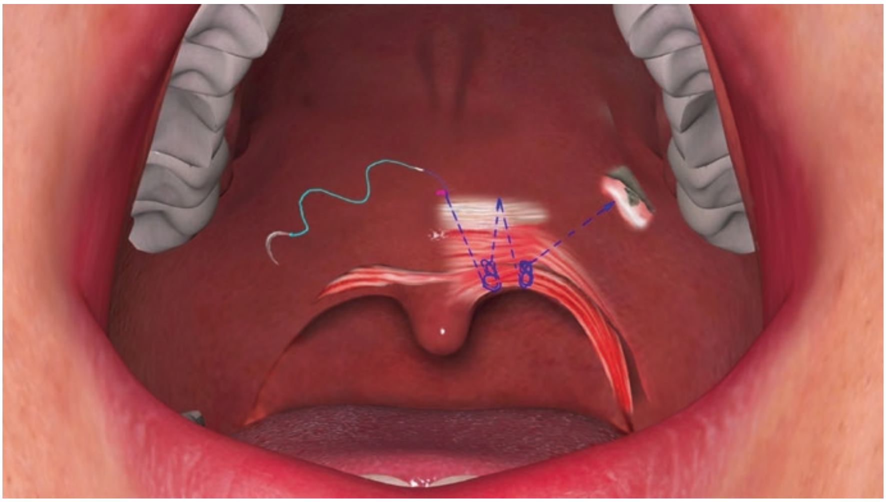


Fig. 12.5 The suture closes the breach in the anterior face of the soft palate and reaches the pterygoid hamulus

In the first description of Alianza technique, the semilunar palatal gap was closed with up and down submucosal passages; since an high incidence of post-operative thread extrusion at that level was observed, we now perform only up and down deep passages into the muscular layer. These anterior passages address the antero-posterior component of the circular velopharyngeal collapse of the patient. The needle is driven spirally downwards along the cephalic two-thirds of the pterygomandibular raphe. It is then directed from laterally to medially through the tonsillar fossa in order to reach and encircle from back to front the vertical fibers of the palatopharyngeal muscle two or three times. If necessary, the same transitions between the pterygomandibular raphe and the palatopharyngeal muscle can be repeated cranially or caudally one or more times (Fig. 12.6).

We recommend to pay attention to the caudal third of the PMR because of the anatomical proximity of the lingual nerve. These lateral passages address the lateral component of the circular velopharyngeal collapse of the patient. Then the needle is driven upwards to the pterygoid hamulus and finally back to the posterior nasal spine (the backstitch). We can complete the same steps on the other (right) side. The threads are cut flush to the mucosa overlying the posterior nasale spine. At the end of the procedure we obtain a functional tenso-structural reconstruction of the velopharyngeal complex (soft palate and lateral pharyngeal walls) with the closure of the anterior palatal wound, the reduction of the palato-oropharyngeal collapsibility and the increase of the lateral and antero-posterior oropharyngeal diameters (Videos 12.2 and 12.3).

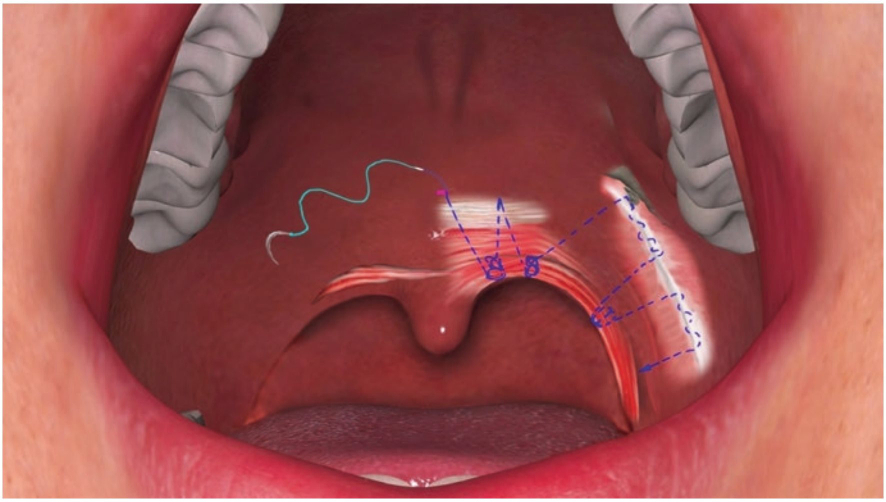


Fig. 12.6 The thread descends spirally along the pterygomandibular raphe and then encircles the palatopharyngeal muscle, translocating it laterally towards the pterygomandibular raphe

12.4 Modified Alianza Technique

In the modified Alianza technique, at the beginning of the surgery, a palatopharyngeal muscle flap in created, as for lateral pharyngoplasty (Fig. 12.7).

In this case the needle encircle this flap two or three times and then is driven laterally to the pterygomandibular raphe (Fig. 12.8).

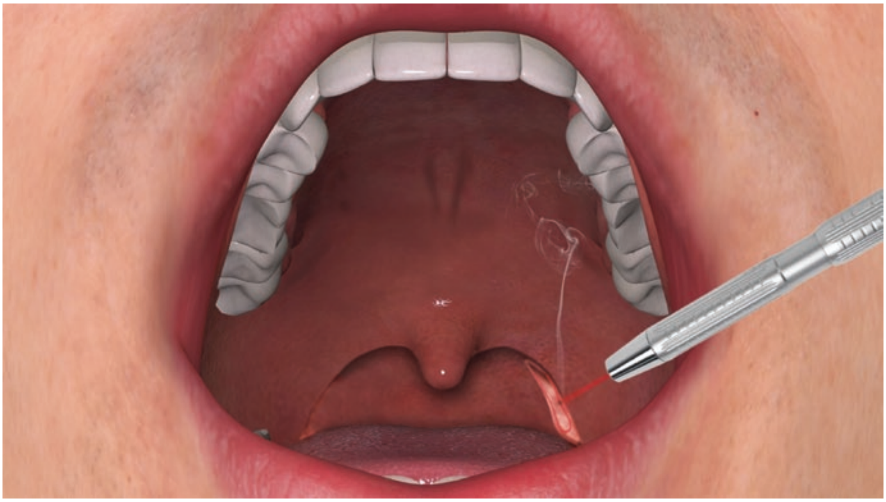


Fig. 12.7 Modified Alianza: a palatopharyngeal flap is created

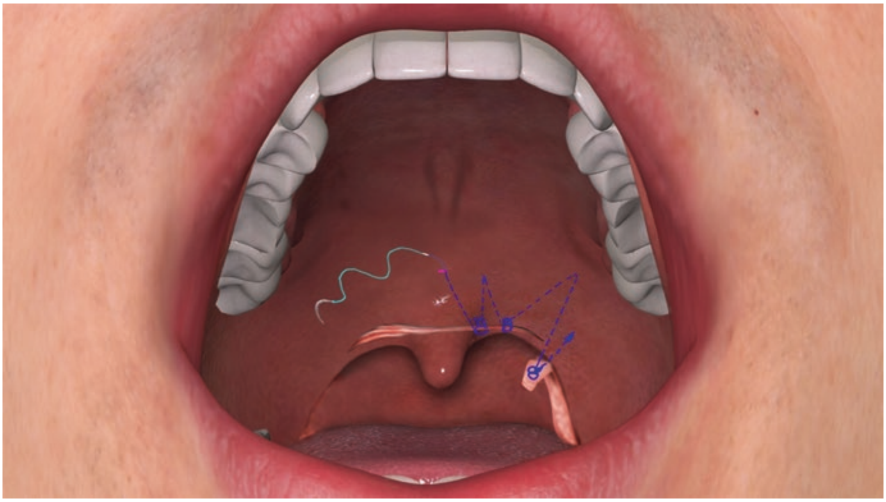


Fig. 12.8 Modified Alianza: the needle encircle palatopharyngeal flap two or three times and then is driven laterally

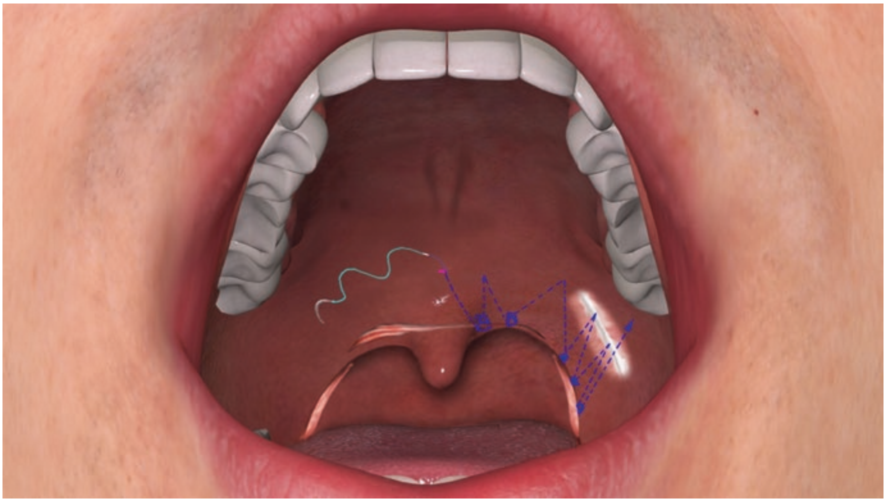


Fig. 12.9 Modified Alianza: transitions between the pterygomandibular raphe and the palatopharyngeal muscle

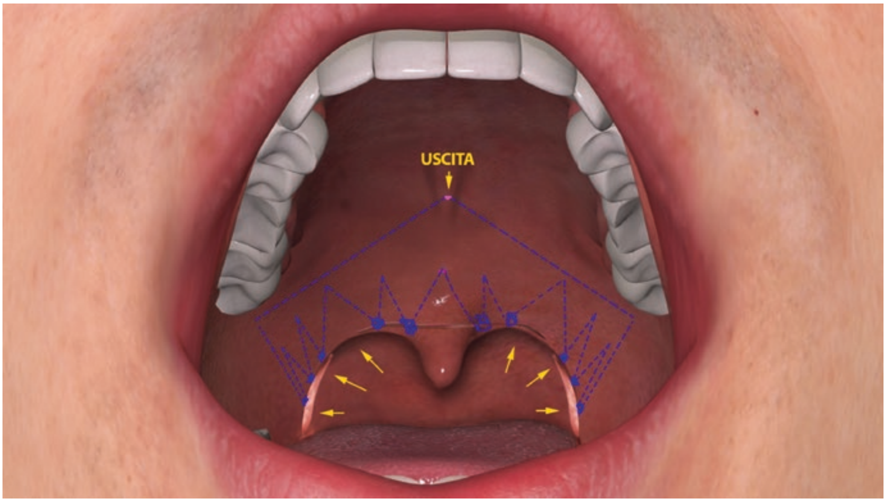


Fig. 12.10 The Backstitch: the thread goes up along the mandibular pterygoid raphe up to the pterygoid hamulus; from here the suture closes to the posterior nasal spine

Also in Modified Alianza the transitions between the pterygomandibular raphe and the palatopharyngeal muscle can be repeated cranially or caudally one or more times (Fig. 12.9).

At this point the needle is returned from pterygomandibular raphe to the pterygoid hamulus; from this point the last submucosal passage is made with the needle that in driven to the posterior nasal spine, performing the backstitch (Fig. 12.10).

This closes the ring on one side, then performing specularly the same procedure on the opposite side using the other half of the suture. At the end of the intervention both of threads exiting the posterior nasal spine have to be cut flush to the palatal mucosa. Two vectors, anterior and lateral, can be created simultaneously to contrast the circular closure pattern.

An endoscopic examination may be performed before the awakening of the patient. We can perform this check directly with a flexible fiberscope or indirectly using a laryngeal mirror, coated with anti-fog or heated: it is important to check the amount of circular expansion of the oropharyngeal sphincter (Videos 12.4 and 12.5).

12.5 Personal Experience

Each patient underwent sleep endoscopy to highlight the circular pattern of vibration and obstruction. It must be considered that in many cases the therapy involves also the application of a MAD (Mandibular Advancement Device), according to sleep endoscopy indications, and therefore the polysomnography is performed with a bite. Before Barbed Snore surgery, the surgical planning is defined with a drawing on the paper (Fig. 12.11).

The postoperative pain lasted an average of 10–12 days in relation also to tonsillectomy.

Postoperative treatment involves the administration of antibiotic therapy and cortisone therapy for 10 days; the duration of pain relief medications varies from patient to patient with the recommendation not to use drugs that promote bleeding (e.g. nonsteroidal anti-inflammatory drugs). The patient is instructed to eat soft and cold foods for 10–15 days. Postoperative clinical evaluations are performed after 7–8 days and after 14–15 days. At the end of the procedure, the tension of the soft

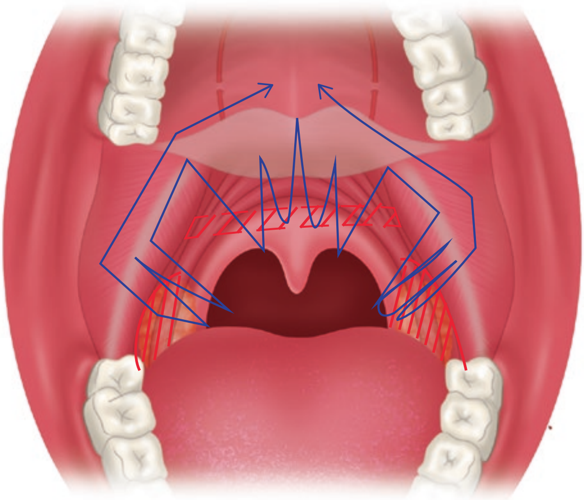


Fig. 12.11 Surgical planning

Fig. 12.12 Alianza technique after 12 months

palate that is obtained may seem excessive in some cases, however it must be taken into account that in the following days, as a consequence of swallowing acts, this tension gradually loosens. Among our operated cases, no patient reported a velopharyngeal insufficiency, no major complications were encountered while only a few minor complications were observed: partial thread extrusion, mucosal granulomas, and anterior wound dehiscence.

In case of postoperative extrusion of the thread, we recommend to wait at least 15–21 days after the surgery; then the extruded portion of the thread can be removed in outpatient setting. Threads can be removed using forceps and cutting instruments; it is not always easy to remove the extruded threads due to the presence of the patient's vivid reflexes and to the size of the tongue.

In our experience, the possible removal of parts of the thread does not reduce the effectiveness of the surgery because the scarring induced by the suture still has a sealing effect [10].

The mucosal granulomas usually appear 60–90 days after surgery, they are asymptomatic and heal spontaneously: in some cases we prescribed a therapy with daily mouthwashes.

Also the anterior pharyngoplasty dehiscence heals spontaneously without any functional impairment.

In Figs. 12.12, 12.13, 12.14, and 12.15 we can observe the postoperative outcomes of Alianza technique.

Fig. 12.13 Alianza technique after 18 months

Fig. 12.14 Alianza technique after 24 months

Fig. 12.15 Alianza technique after 5 years

12.6 Conclusions

In OSAHS patients with circular velopharyngeal pattern as highlighted by sleep endoscopy, the Alianza pharyngoplasty represents an effective, non-resective and safe procedure. It allows to obtain a functional and durable tenso-structural reconstruction of the velopharyngeal complex (soft palate and lateral pharyngeal walls) thanks to the creation of anterior and lateral vectors that counteract the hyper-collapsibility of the palate-oropharyngeal complex.

12.7 Barbed Antero-Lateral Pharyngoplasty (BALPh)

Also in this technique tonsillectomy is performed if tonsils are present (Fig. 12.16).

This surgical technique originates from the Alianza and is substantially differentiated by the resection area of the mucosa and submucosa at the level of the soft palate. The result is a modification of the suture which in any case has the purpose of obtaining anterior and lateral vectors.

BALPh arises from the need to reduce the scar at the level of the soft palate of Alianza and to avoid excessive edema of the uvula in the postoperative, sometimes lasting over time.

The idea is to create two antero-posterior vectors in the supratonsillar region, close to the upper third of the pterygomandibular raphe, without involving the median region of the soft palate.

In this way a significantly reduced excision of the mucosa and submucosa is performed compared to Alianza (Figs. 12.17 and 12.18).

In the BALPh technique, Barbed sutures are used, but instead of using one thread as in the Alianza technique, two are needed, one for each side.

The starting point of the suture is located at the level of the Hamulus/upper third of the raphe (Fig. 12.19).

With one half of the thread (up to the inversion point of the beards), the medial suture is performed: the breach created in the mucosa is closed, the muscle is hooked and brought towards the hamulus with 2–3 steps (as in the BAPh) (Fig. 12.20), finally a backstitch is performed to the posterior nasal spine.

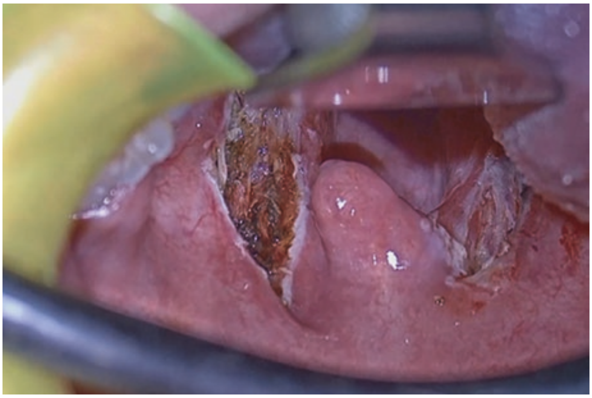


Fig. 12.16 Tonsillectomy

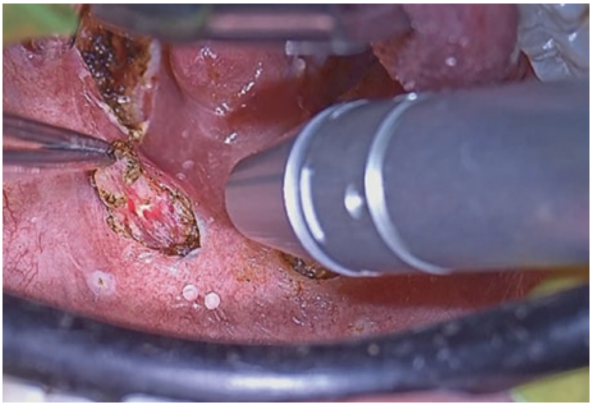


Fig. 12.17 Resection area of the mucosa and submucosa with CO_2 laser

Fig. 12.18 Soft palate at the end of excision of two mucosa-submucosa island

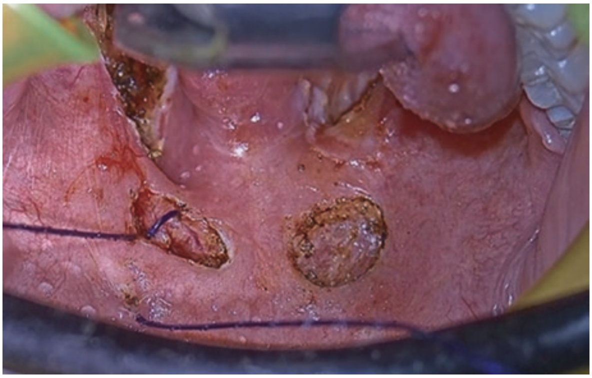


Fig. 12.19 Suture starts at the lev of the Hamulus/upper third of the raphe

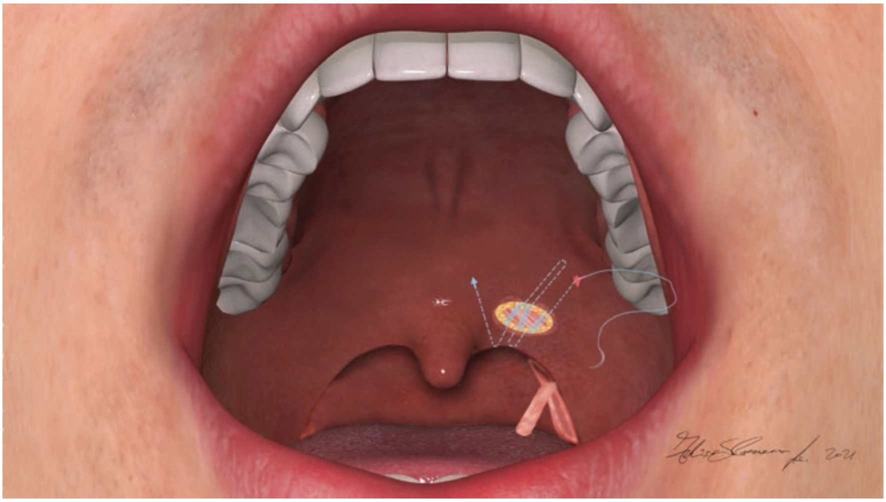


Fig. 12.20 The first half of the thread (up to the inversion point of the beards) closes the breach with two-three steps towards the hamulus

The second half of the thread (from the inversion point of the beards) mimics the path of lateral pharyngoplasty, engaging the previously prepared flap of the palato-pharyngeal muscle (Fig. 12.21). A backstitch is also performed towards the posterior nasal spine–palatine aponeurosis.

In this way a predominantly antero-posterior vector is created at the level of the supratonsillar region and a lateral vector at the level of the lateral wall of the

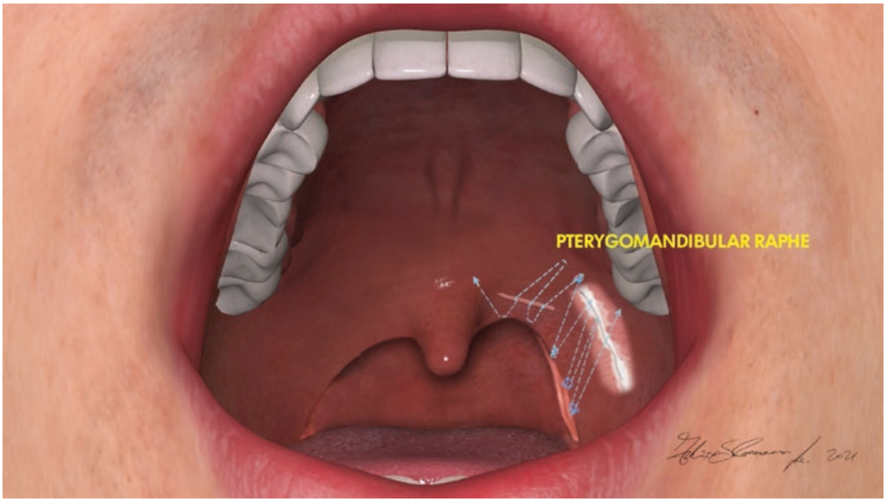
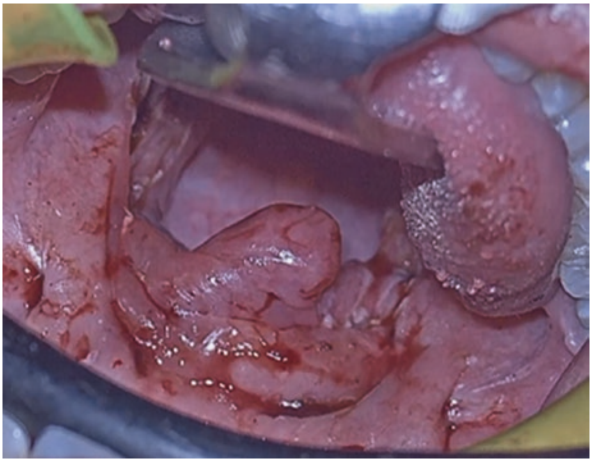


Fig. 12.21 The second half of the thread (from the inversion point of the beards) creates a lateral vector

Fig. 12.22 Circular opening at the end of the suture



oropharynx: these two vectors create a circular opening at the level of the oropharyngeal sphincter (Figs. 12.22 and 12.23).

This surgical technique was recently devised and the preliminary results are very positive, comparable to Alianza, but with a decidedly reduced discomfort at the level of the uvula and the soft palate (Videos 12.6 and 12.7).

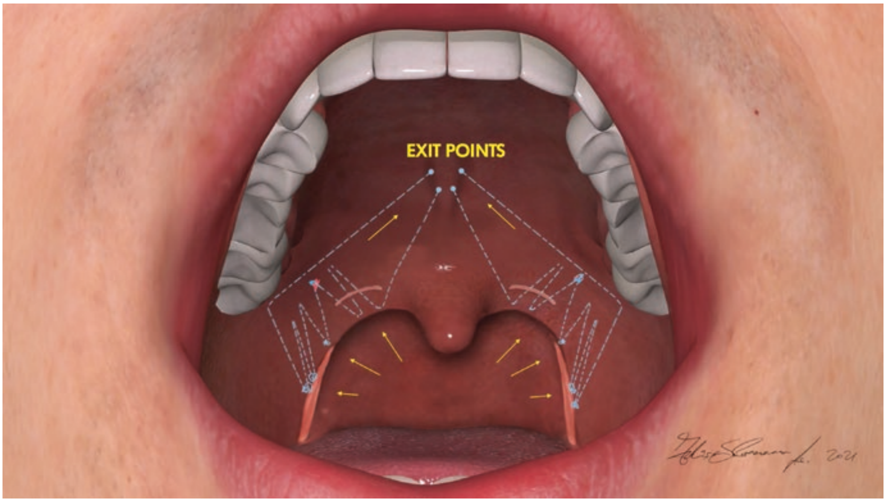


Fig. 12.23 Antero-posterior vector is created at the level of the supratonsillar region and lateral vector at the level of the lateral wall of the oropharynx: these two vectors create a circular opening

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Barbed Snore Surgery: The Learning Curve

13

Federico Leone, Silvia De Santi, and Fabrizio Salamanca

13.1 Introduction

The learning curve (LC) illustrates the improvement in performance of a specific procedure over time, therefore it can be described as a graphical representation of the relationship between learning effort (horizontal axis) and learning outcome (vertical axis).

The LC represents how the measures of learning, i.e. the outcomes change with experience: the surgeon starts with a certain level of performance, which increases with experience and then stabilizes, as the curve reaches a plateau. Nevertheless, this curve may undergo a decreasing trend after technical expertise is achieved, maybe due to the excessive confidence of the surgeon or the excessive difficulty of the cases. In this study we aimed to determine the LC in terms of mean operation time of a junior surgeon in performing a tonsillectomy with barbed lateral pharyngoplasty (tBLPh) procedure compared with experienced surgeons. To the best of our knowledge, this is the first work regarding LC in barbed snore surgery (BSS).

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*, https://doi.org/10.1007/978-3-030-96169-5_13

13.2 Study Design

This study was conducted at the Department of Otorhinolaryngology of Humanitas San Pio X, a referral center for the management of sleep-related breathing disorders. All patients signed an informed consent form for the use of data for scientific purposes, and the study was carried out in accordance with the principles of the Helsinki Declaration. All patients who underwent tonsillectomy with barbed lateral pharyngoplasty between 1 January 2018 and 31 December 2020 were included. Four different surgeons (two junior surgeons and two senior surgeons) performed all the procedures. Patients were divided in two different groups based on surgeon experience (Junior surgeons, Group A; Senior surgeons, Group B). The two senior surgeons performed more than 100 barbed pharyngoplasty, while junior surgeons never performed this kind of surgery before the initiation of the present study. All surgeons were well-trained in tonsillectomy procedure.

During the preoperative diagnostic work-up each patient was subjected to a complete physical examination, endoscopic evaluation, polysomnographic study (PSG), and drug-induced sleep endoscopy (DISE). The surgical procedure included a quantum molecular resonance (QMR) tBLPh. For more details about the surgical technique we remand to the related Chap. 11. All the surgical procedures were performed under general anesthesia and oro-tracheal intubation.

13.2.1 Data Acquisition and Statistical Analysis

Data were prospectively collected and stored in a Microsoft Excel spreadsheet. The following baseline patients' characteristics were collected before surgery: age, sex, body mass index (BMI), tonsil grading, Mallampati score, Epworth Sleepiness Scale (ESS), and poligraphy data. Operative time, intra-operative blood loss, intra- and post-operative complications, and hospitalization time were collected. Categorical variables were summarized by counts and percentage, while continuous variables were reported as means ± standard deviations (SD) or as median ± interquartile range (IQR: 25th and 75th) if the values were not normally distributed. The D'Agostino and Pearson normality test was used to verify whether data were normally distributed. The Chi-square test was used for the comparison of the categorical patients' baseline characteristics among the two groups, while the Student's *t*-test or the Mann–Whitney test were used for the comparison of the continuous variables. Comparison between the two groups in terms of operative time, intra- and post-operative complications, and hospitalization was performed using a Fisher's exact test or a Student's *t*-test, as appropriate. The change in the operative time during the course of the surgery series was evaluated using a logarithmic curve-fit regression analysis. Data are presented as a scatter plot with 95% Confidence Interval (CI). Statistical analyses were performed using the statistical package Stata, version 13 (Stators, College Station, TX). Statistical significance was defined as $p < 0.05$.

13.3 Results

A total of 144 consecutive patients (F: 27; mean age: 47.5 years, SD 9.7, range 23.0–71.0) underwent barbed pharyngoplasty and tonsillectomy during the study period. In particular, a total of 49 (F: 7; mean age: 47.5 years, SD 9.5, range 29.0–66.0) procedure were performed by junior surgeons, while the remaining 95 patients (F: 20; mean age: 47.5 years, SD 9.8, range 23.0–71.0) were treated by senior surgeons. Baseline patients' characteristics are shown in Table 13.1.

Senior surgeons completed the procedure in 59.7 min (SD 9.0), while junior surgeons needed 77.9 min (SD 19.5) ($p < 0.05$). No intra-operative complications were observed, and intra-operative blood loss were minimal in both groups. No difference was measured in terms of hospitalization time ($p = 0.34$), given that almost all patients (99.3%) were discharged the post-operative Day 1. Only one patient treated by a junior surgeon was discharged on the second post-operative day due to moderate post-operative palatal edema. Only one post-operative bleeding resolved with conservative treatment was detected in both groups (Group A, 1%; Group B, 2%; $p = 0.99$).

A scatter plot showing the change in the operative time during the course of the surgery series is reported in Fig. 13.1 for both groups. Junior surgeons showed a positive trend in the reduction of operative time ($r = -2.25$, 95% CI: −2.66 to −1.84; $p < 0.05$; Fig. 13.1a), while senior surgeons showed no change in the operative time ($r = 0.003$, 95% CI: −0.13 to 0.13; $p = 0.96$; Fig. 13.1b), as expected. Mean operative time of junior surgeons was not significantly different from senior surgeons after 12 surgical procedures ($p = 0.08$).

Table 13.1 Patients' characteristics

	Total	Senior	Junior	*p* value
Age	47.5 ± 9.7	47.5 ± 9.8	47.5 ± 9.5	0.99
BMI	27.0 ± 3.4	27.0 ± 3.6	26.9 ± 3.3	0.92
Tonsil grading				0.61
Grade 1	73 (51.4%)	47 (50.0%)	26 (54.2%)	
Grade 2	39 (27.5%)	29 (30.8%)	10 (20.8%)	
Grade 3	22 (15.5%)	13 (13.8%)	9 (18.7%)	
Grade 4	8 (5.6%)	5 (5.3%)	3 (6.2%)	
Mallampati score				0.04
Class 1	6 (4.4%)	1 (1.3%)	5 (10.6%)	
Class 2	29 (21.5%)	17 (19.3%)	12 (25.5%)	
Class 3	80 (59.3%)	55 (62.5%)	25 (53.2%)	
Class 4	20 (14.8%)	15 (17.0%)	5 (10.6%)	
ESS	7.7 ± 4.3	7.8 ± 4.6	7.5 ± 3.7	0.79
AHI	25.5 (IQR 11.1–43.7)	24.1 (IQR 11.1–43.7)	27.8 (IQR 11.1–43.7)	0.32
ODI	22.9 (IQR 9.2–38.6)	21.5 (IQR 7.9–38.5)	24.7 (IQR 9.7–38.6)	0.43

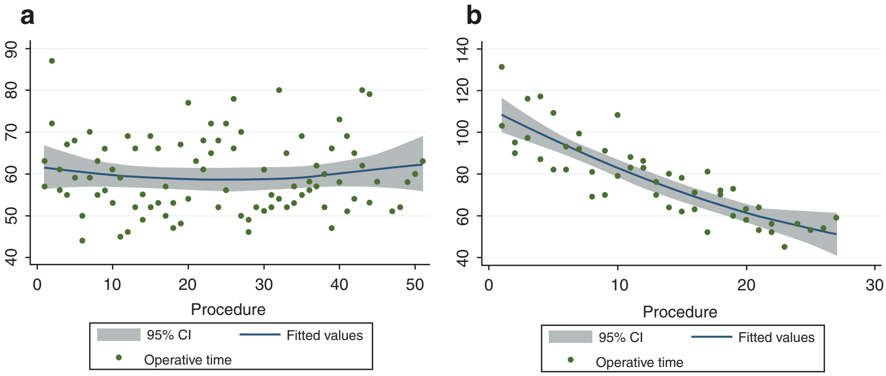

Fig. 13.1 A scatter plot showing the change in the operative time during the course of the surgery series. (**a**) junior surgeons. (**b**) senior surgeons

13.4 Discussion

Learning curves are a useful tool for many aspects of medical research and education. Our aim was to define the learning curve in barbed snore surgery [1]. The learning curve (LC) illustrates the improvement in performance of a specific procedure over time. Although the fact that performance improves with time and practice is now an intuitive perception, it was Wright, an aeronautical engineer, who first described the aforementioned concept in 1936, as he realized that the number of man-hours required to build an airplane component decreased as the quantity of production increased. In medicine, learning curves are of greater importance and they have been used since the 1980s to describe the uptake of new surgical skills for minimally invasive surgery. The LC represents how the measures of learning (i.e., the outcomes) change with experience: the surgeon starts with a certain level of performance, which increases with experience and then stabilizes, as the curve reaches a plateau. Nevertheless, this curve may undergo a decreasing trend after technical expertise is achieved, maybe due to the excessive confidence of the surgeon or the excessive difficulty of the cases [2].

A general consensus on how to assess the quality of articles describing LC does not exist in the literature. An important aspect of measuring the learning curve is choosing the right variables. There are two main types of variables: measuring the surgical process or measuring patient outcomes. Measures of surgical process include variables such as time to complete the procedure or completion rate of the procedure, conversion rate from laparoscopic to open surgery, resection and margin involvement in cancer surgery, etc. [3] Measures of patient outcomes include amount of blood loss, length of hospital stay, intra-operative/post-operative complications, mortality, etc. [4] Several papers related to surgical learning curve have been published for several Otolaryngology – Head and Neck Surgery procedures (e.g. cochlear implantation, endoscopic sinus surgery, tonsillectomy, septoplasty, sialoendoscopy, rhinoplasty)[5]:

To the best of our knowledge, this is the first work regarding LC in BSS. The analysis of the learning curve for each junior shows the same slope of the overall curve (Fig. 13.1). Mean operative time of junior surgeons was non significantly different from senior surgeons after 12 surgical procedures ($p = 0.08$).

No significant differences were observed in terms of the intra-operative blood loss, intra- and post-operative complications, and hospitalization time. In particular, only one post-operative bleeding resolved with conservative treatment was detected in both groups. These results confirm those reported in the literature (The incidence of secondary hemorrhage is between 0.1% and 4.8% [6]) and allow us to confirm that all surgeons are equivalent in performing a tonsillectomy. Of note, tBLPh does not increase the risk of post-surgical bleeding. Our result suggest that BSS can be safely performed by a unexperienced surgeon if preceded by a good training. Furthermore, many sleep surgeons will surely incorporate these techniques that was recently introduced as an alternative to conventional palatal surgery, in their surgical options able to treat retropalatal collapse. We believe that our data will facilitate the widespread of this promising OSA surgery. In this context, both surgical simulators [7] and ex vivo [8] surgical models have been recently proposed to expedite the surgical learning curve for BSS in untrained ENT surgeons. These tools may further simplify the acquisition of the surgical skill needed to adequately perform BSS in many ENT centers, and are surely recommended before performing the real surgery.

13.5 Conclusion

Learning curves are a useful tool for many aspects of medical research and education. Our aim was to define the learning curve in BSS. LC in this kind of procedure is fast and the junior surgeon (e.g. ENT resident) could autonomize itself in a short time with a progressive reduction of the operative time and an improvement of surgical performances. In fact an unexperienced surgeon need to perform on average just over ten procedures to reach the senior surgeon's operative timing without differences in terms of complications. In conclusion tBLPh is a conservative and simple technique with a fast learning curve and more or less devoid of complications if preceded by a good training.

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Barbed Reposition Pharyngoplasty (BRP)

14

Claudio Vicini, Federico Faedi, and Giannicola Iannella

Never give up

14.1 Introduction to Barbed Reposition Pharyngoplasty (BRP)

The first idea of a new and original palate technique started to grow up inside Forlì's Group on the late 2014 [1–4].

The ideas started thanks to our previous experience on palate procedures for sleep disordered breathing that are summarized in Fig. 14.1.

After a long initial period dominated by laser-assisted uvula-palate-pharyngoplasty (LAUP) (1996–1998) according to Kamami, uvulopalatopharyngoplasty (UP3) as described by Simmonds became for a long time our workhorse (1998–2010). In selected cases was applied uvulopalatal flap (UPF) according to

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_14

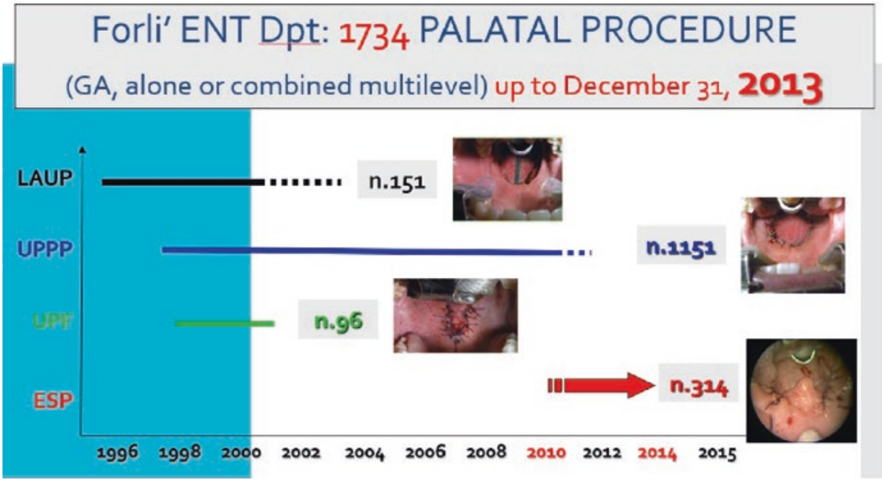

Fig. 14.1 Morgagni Pierantoni Hospital experience in palate procedures for sleep disordered breathing from 1999 to now

Powell and Riley, and in even more particular ones was carried out Transpalatal Advancement Pharyngoplasty (TPA) according to Tucker Woodson [5]. Since 2010 the Expansion Sphincter Pharyngoplasty (ESP) according to Pang et al. [6] became our first choice as a single level and as a multilevel procedure. For a long time ESP proved to be in our hands an effective way for addressing palate snoring and palatal collapse. In the special setting of robotic multilevel ESP was demonstrated more powerful in our hands than UP3 in reducing AHI and LOS. Nevertheless, we were daily stimulated by our younger team members and by residents and fellows to overcome some technical difficulties of ESP, which were very common in their first cases. Point number 1: raising the palate-pharyngeal flap. Beside the challenge (time and skill requested) to dissect a muscle bundle of proper length and thickness, the main concern was the risk of parapharyngeal space invasion and possible significant bleeding. Point number 2: how to locate the hamulus and how to be able to secure the suture around it without cutting the mucosa. Additional points arose by the post-op follow-up and by a careful analysis of ESP by a young Bioengineer who joined our Group for 1 year. It was commonly apparent that the ESP post op shape of the oropharyngeal inlet tends to assume a “Hearth Shape,” wider superiorly and narrow inferiorly. It is explained in our opinion for the single point of traction at the base of the palate-pharyngeal flap, much less effective in the lower half of the inlet. It means that the enlarging action of ESP is more effective superiorly but less powerful inferiorly. Last but not least, the single tip suture used for pulling laterally the flap. Basically, the entire procedure relied upon the stability of a single stich in the tip of the flap. Even if it is possible to pass a double suture and/or to reinforce the sutures by means of an additional suture surrounding the flap tip, it is well known how difficult it is to suture any skeletal muscle passing the threads parallel to the muscle fibers. The risk of tearing up the muscle and reducing or lose the tension seems too high with this procedure.

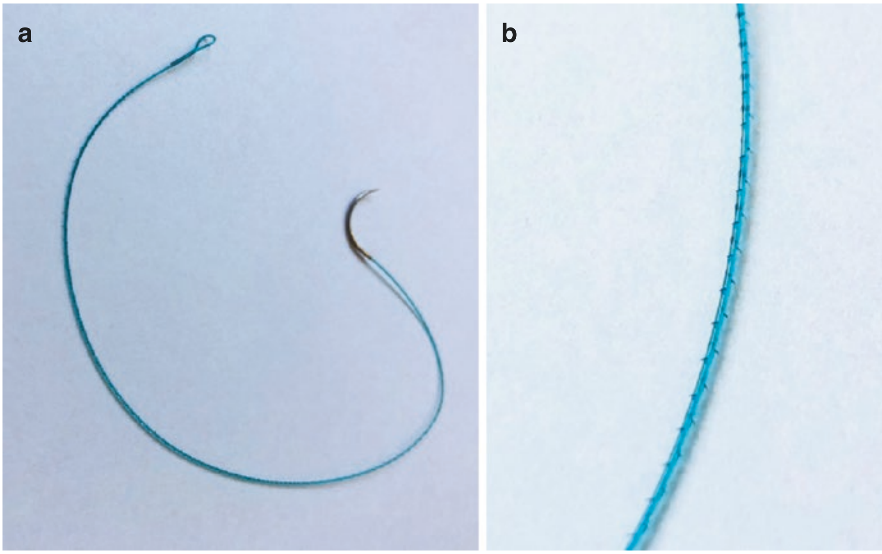

Fig. 14.2 (**a**, **b**) Bidirectional barbed suture 2-0 V-loc 180

Along the way of developing a useful improvement of ESP and in order to overcome the described pitfalls, Mario Mantovani with his Roman Blind technique suggested us a simple, cheap but really smart technology to use in velo-pharyngeal surgery: the barbed sutures [7] (Fig. 14.2).

It became the cornerstone for building up the new technique in its original version. We named it Barbed Reposition Pharyngoplasty. The basic idea was to develop a simplified version of ESP, easier to perform and possibly quicker, with not inferior efficacy for addressing snoring and sleep apnea. An additional goal for our Group was also to provide a solution to operate the palate which could fit into our single step multilevel robotic procedure including TORS in the tongue base and supraglottis [8]. The main features of BRP were defined since the beginning:

1. Instead of raising a pedunculated flap from the palate-pharyngeal muscle, it was just released (partially cut) in its inferior aspect in an easy, quick, and safe way, permitting a sufficient mobilization of the posterior pillar. It was inspired to the relocation technique by Li in Taiwan [9].
2. Hamulus was replaced by the pterigo-mandibular raphe, a strong fibrous structure, much easier to locate and to use as a long cable for sustaining the palate-pharyngeal muscle. Raphe is the landmark routinary located by dentistry for inferior alveolar nerve blocking.
3. The entire palatopharyngeal muscle was repositioned toward the whole raphe, reshaping the new oropharyngeal inlet in a more square-like form (Fig. 14.3)
4. Moreover, it was devised a main passage of the suture between the superior 1/3 and inferior 2/3 of the palatopharyngeal muscle and a properly balanced tension of the barbed, in order to “steal” and integrate a leg of posterior pillar into the

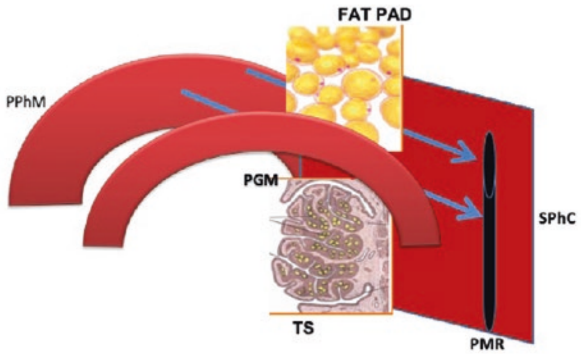

Fig. 14.3 Schematic technique of palatopharyngeal muscle relocation in Barbed Reposition Pharyngoplasty towards the pterygomandibular raphe removing the interposed tissues (tonsils and supra-tonsils fat; palatopharyngeal muscle (PPhM); supra-tonsil fat tissue (FAT PAD); tonsil tissue (TS); pterygomandibular raphe (PMR); Superior pharyngeal constrictor muscle (SPhC))

free edge of the soft palate. This maneuver overemphasizes the transversal dimension of the oropharyngeal inlet producing a final more squared shape.

5. The sutures between posterior pillar and raphe are devised as a coil of many threads instead of a single suture, with the peculiar feature to be oriented at 90° compared the muscle fibers direction, therefore making the suture much more stable [10, 11].
6. The use of bidirectional barbed sutures gave the final touch of simplicity: no knots required, enhanced stability, shorter time of execution. In BRP, differently from Mantovani Roman Blind technique, barbed suture are not only an incisionless solution for providing a rigid internal scaffold. In BRP barbed suture are truly anchoring sutures assisting the transposition of released muscle bundles in a new more favorable position. Targeted minimally invasive muscle trans-sections are planned in order to allow a tensionless and more stable muscle repositioning. After more than 700 BRPs in our Group series we didn't register any short- or long-term swallowing trouble possibly related to the partial cut of the palate-pharyngeal bundle. Furthermore, within our early series of ten cases, when we tried in a couple of palates to force the new position without releasing the muscle, we observed a partial breakdown of the sutures [12].

Barbed suture give us an increased degree of freedom in customize our action of relocation accordi to each different case. The running suture may be modulated in an endless number of solutions (suture direction and angle, tension, number of passages, simple lateral sutures or additional midline crossing sutures, etc.). In this way BRP fit to the single case anatomy according to the shape of the pharynx and, last but not least, according to the will and the experience of the single surgeon. The basic idea is that "one fit all" [3, 13].

The schematic technique is shown in Figs. 14.4, 14.5, and 14.6.

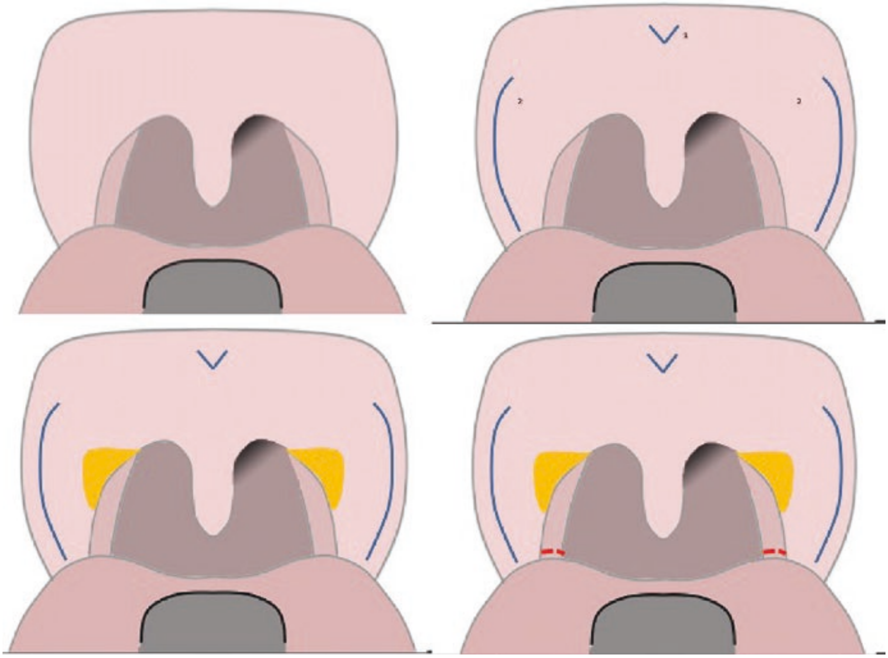

Fig. 14.4 Landmarks of the BRP: pterygomandibular raphe (blue arcuate line), posterior nasal spine (blue open triangle), supratonsillar tissue removed (yellow), lower portion of the pharyngeal palate muscle sectioned (red line)

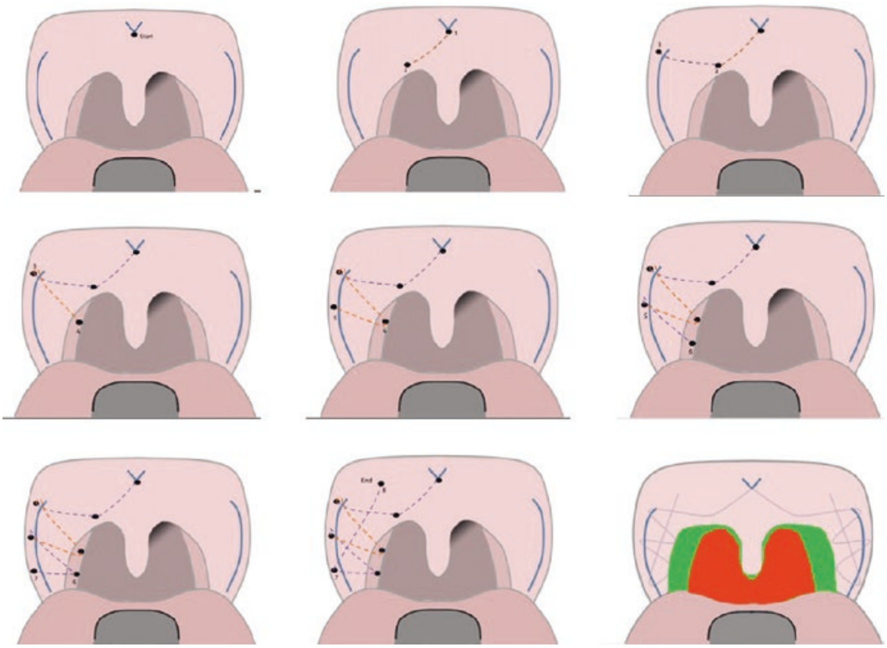

Fig. 14.5 Schematization of BRP steps

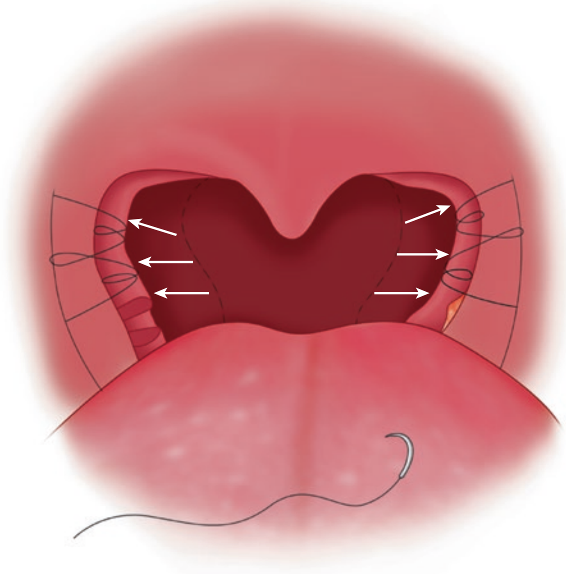

Fig. 14.6 Schematization of BRP technique

14.2 Barbed Reposition Pharyngoplasty development

A summary of the different steps of BRP development are summarized in Fig. 14.7. Most of the listed steps will be described in specific chapters of this monography.

Cadaver lab in the USA and Italy gave us overall feedback about anatomical feasibility of the devised solutions. The first study was run to check surgical feasibility, safety, and efficacy. Biomechanical engineering studies gave us invaluable information starting from a vectorial model of the procedure. The retrospective multicenter ones convinced us that BRP may work in different surgical hands, with different volumes and expertise. Questionnaires were developed and administered for getting a semi-quantitative patient perspective. The biomechanical study in the frog confirmed us that transversal sutures are more stable than longitudinal sutures. Our RCT and the first systematic review were a scientific cornerstone from the Evidence Based Medicine point of view. The many BRP modifications convinced us that only a strong tree trunk may produce many green branches [14].

BRP was at the beginning, it is now and it will be in the future a never-ending story, a work in progress, a dynamic process of improvement. Every single case, with its unique anatomical a patho-physiological profile, gives us information of paramount importance for improving the technique.

It was the case of the two main development we were able to introduce after the initial description:

1. The introduction of the midline crossing suture for snoring inspired by the Pillar procedure.
2. The supratonsil fat dissection as suggested by Tucker Woodson.

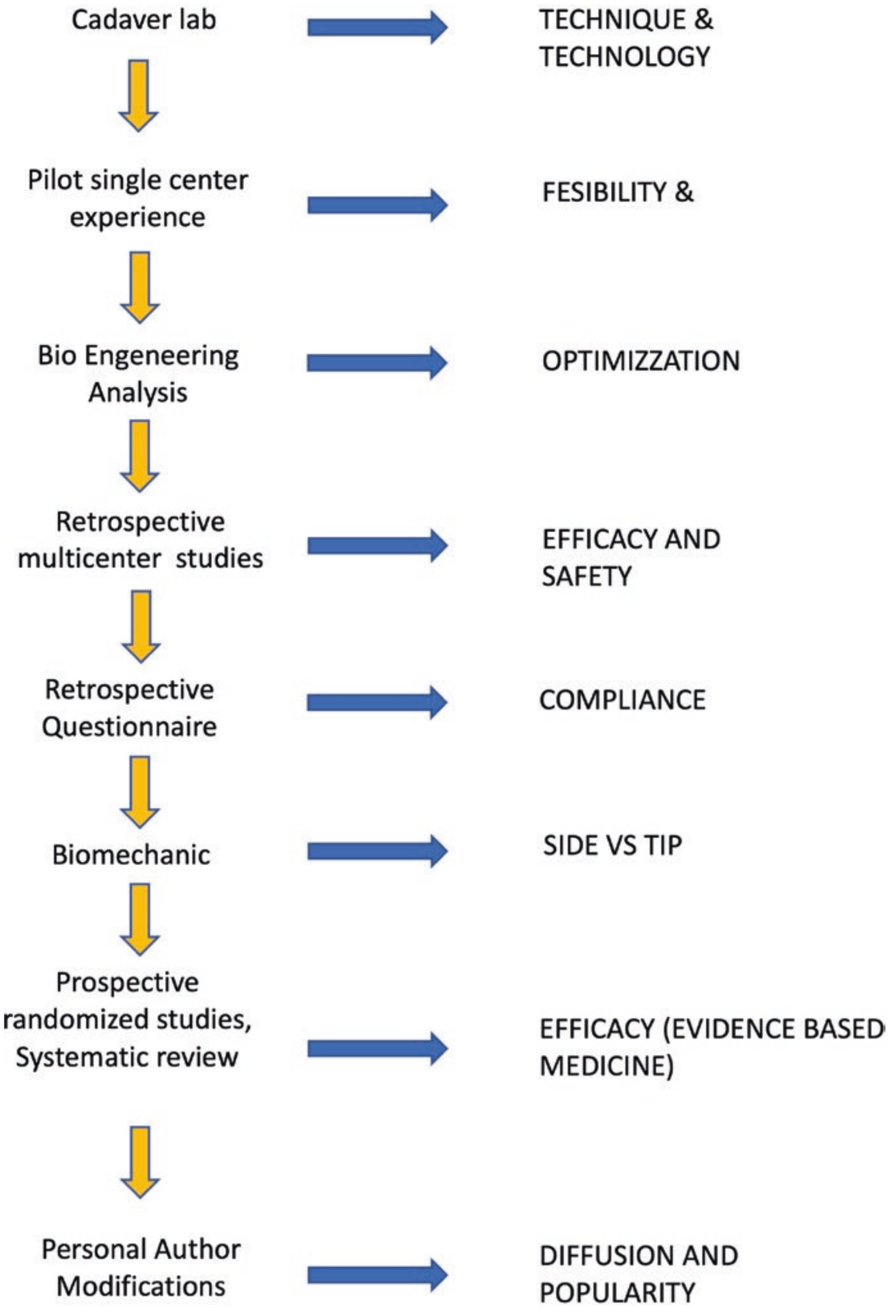

Fig. 14.7 Steps of Barbed Reposition Pharyngoplasty development

It is the case of the careful follow-up of our patients which gave us a strong feedback about the suture extrusion and exposure, its impact into the patient perspective and into the final outcomes [15].

14.3 Bio-Engineering Modeling

BRP provides a suspension of the posterior pillar to the pterygomandibular raphe, displacing the palatopharyngeal muscle to a more lateral and anterior position. The effect is an enlargement of the oropharyngeal inlet as of the retropalatal space. In the BRP technique only a weakening of the inferior portion of the palatopharyngeal muscle is performed.

One negative aspect of all lateral pharyngoplasty should be noted: these techniques may lead to an excessive weakening of palatopharyngeus muscle fibers due to its excessive traction during relocation. In case of excessive stretching of the muscle, or breakdown of muscle fibers during these procedures the results is the loss of the entire pulling force [10, 13, 16–20].

The force of traction expressed by multiple elements, such as a direction and magnitude, can be expressed as a vector or vector quantities.

The vector is characterized by a magnitude or module or intensity, a direction and an application point and is usually represented as a segment oriented by an arrow (Fig. 14.8).

BRP technique could be explained through vector analysis. In this technique the pharyngeal palate muscle is relocated towards the pterygomandibular raphe according to multiples specific vectors which, starting from the palatopharyngeal muscle, have an upward (Patient's head) and lateral (pterygomandibular raphe) direction. The vector force is directly related to the traction applied by the surgeon to the barbed wire [21].

Figures 14.3 and 14.9 schematized the vector analysis of the relocation of the pharyngeal palate muscle towards the pterygomandibular raphe. The final result

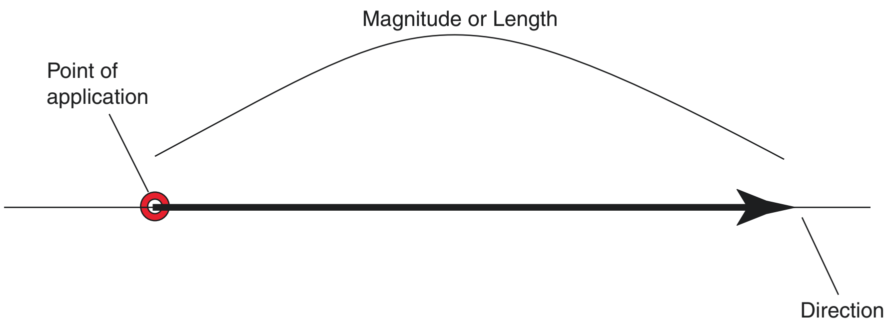

Fig. 14.8 Schematization of a "vector"

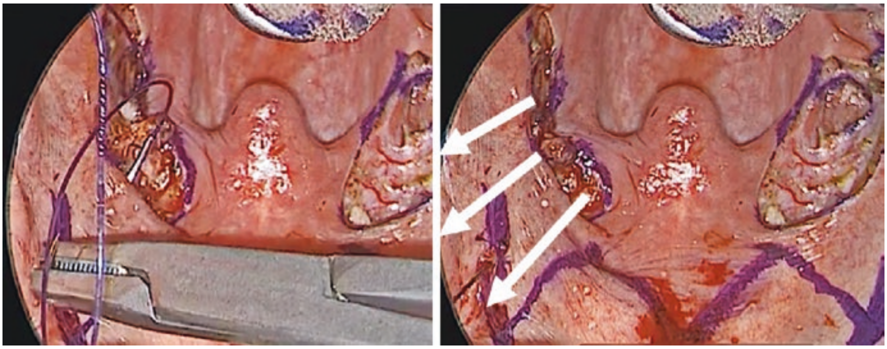

Fig. 14.9 Schematized the vector direction in the relocation of the pharyngeal palate muscle towards the pterygomandibular raphe

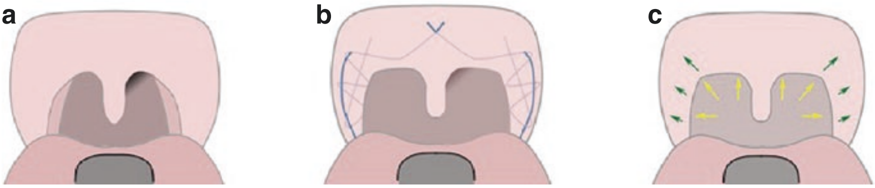

Fig. 14.10 (**a**–**c**) Enlargement of the oropharyngeal and retro-velar space with a three-dimensional spatial expansion according to the vector analysis

of the combination of these multiple vectors acting on the palato-pharyngeal muscle is a stable enlargement of the oropharyngeal and retro-velar space, with a three-dimensional spatial expansion in multiple directions (Fig. 14.10) in order to raise and lift the patient's palate. The effect of muscle relocation, according to a vector analysis, is expressed as a tension exerted on the palato-pharyngeal muscle.

We have evaluated the effect of BRP on muscle relocation through an experimental measurement of the muscle tension obtained during five BRP surgeries.

To evaluate the tension applied to muscle during the BRP surgery, we used a dynamometer (Wunder dynamometer, 2 kg with 25 g precision). During the BRP procedure, the surgeon measured, using the dynamometer, the traction force of the needle (Fig. 14.11).

In order to obtain a correct evaluation of the force applied in all velo-pharynx during the entire surgery, we measured the tension in different points as indicated in Fig. 14.12. Eight palatal points have been tested in each patient.

Table 14.1 summarizes the average value of muscular tension obtained in the five patients tested.

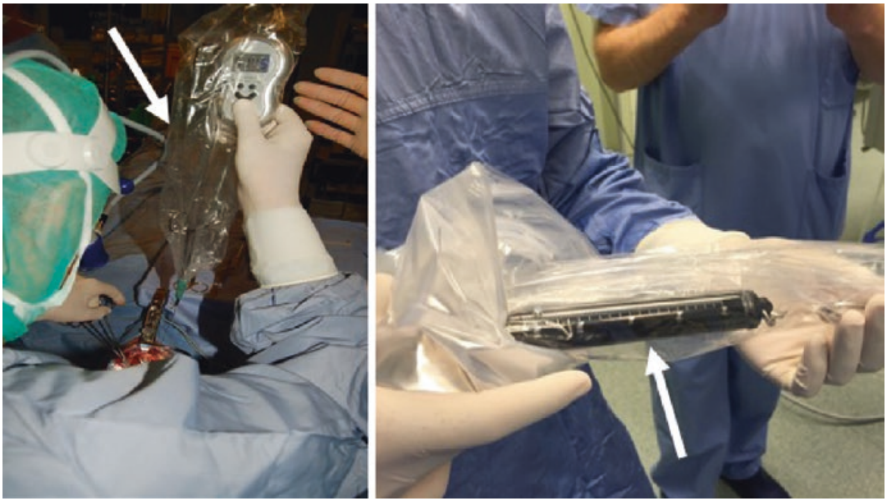

Fig. 14.11 The surgeon using the dynamometer (arrow) measured the force of traction applied to the palate-pharyngeal muscle during BRP surgery

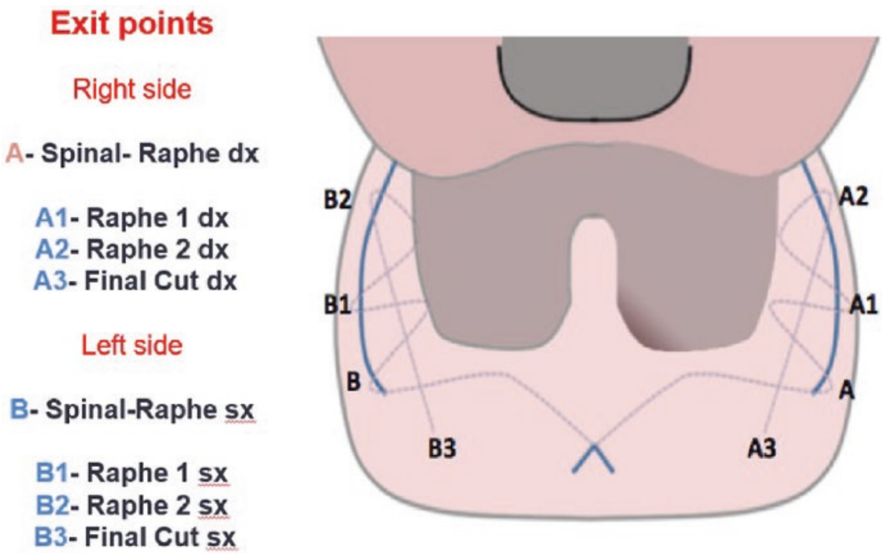

Fig. 14.12 Points of muscle tension measured during BRP surgery

Table 14.1 Average values of muscular tension obtained during BRP surgery in five patients tested

Measurement point	Medium tension (Newton)[a]
A	2664
A1	1638
A2	2844
A3	2599
B	2656
B1	2280
B2	2108
B3	1442

[a]1 gram to Newton = 0.00981 Newton

14.4 Biomechanical Studies

In order to test biomechanical aspects of expansion sphincter pharyngoplasty (ESP) and BRP techniques we have designed an experimental study.

This experimental stress test simulated the effect of traction of the human palatopharyngeal muscle in a similar animal muscle model (frog thigh muscle). Besides, the effect on the muscle traction of two surgical techniques (BRP and ESP) has been compared [21].

Frog thigh muscle was used for an experimental protocol study. The muscle of frog was considered an excellent specimen for simulating the two surgical techniques instead of the palatopharyngeal muscle; its length, size, and muscular consistency are very similar to the ones of the palatopharyngeal muscle.

All frog muscle specimens employed in the experimental study had a similar length and thickness (length 1.8 ± 0.2 cm thick 0.8 ± 0.2 cm thick). The muscle was anchored using a small hook to a wooden tablet (Fig. 14.13a).

A Vicryl 3-0 suture of barbed suture was knotted to the frog muscle in the same way as it is usually performed in the two different pharyngoplasty techniques (Fig. 14.13b–d). The other extremity of the suture was attached to traction scales (Fig. 14.13c, d). The traction scales were used to measure the weight relative to the force that had to be exerted to obtain muscle damage/breakage (Fig. 14.13c, d).

The simulation of the ESP technique was made performing a “Figure 8” suture with 3-0 Vicryl at one of the muscle extremities. As is normally done in the ESP technique, traction was performed with a vector having a longitudinal direction to the muscle fibers until muscle breakage was observed (Fig. 14.14a–d).

In the simulation of the BRP technique the suture with 3-0 Vicryl was made by repeatedly passing the needle through the middle of the muscle as is normally done in the BRP technique (see specific section above). Traction was performed with a vector perpendicular to the direction of the muscle fibers, until muscle breakage was observed (Fig. 14.15a–d).

In both simulations, traction of the suture and muscle was continued until the muscle rupture was observed.

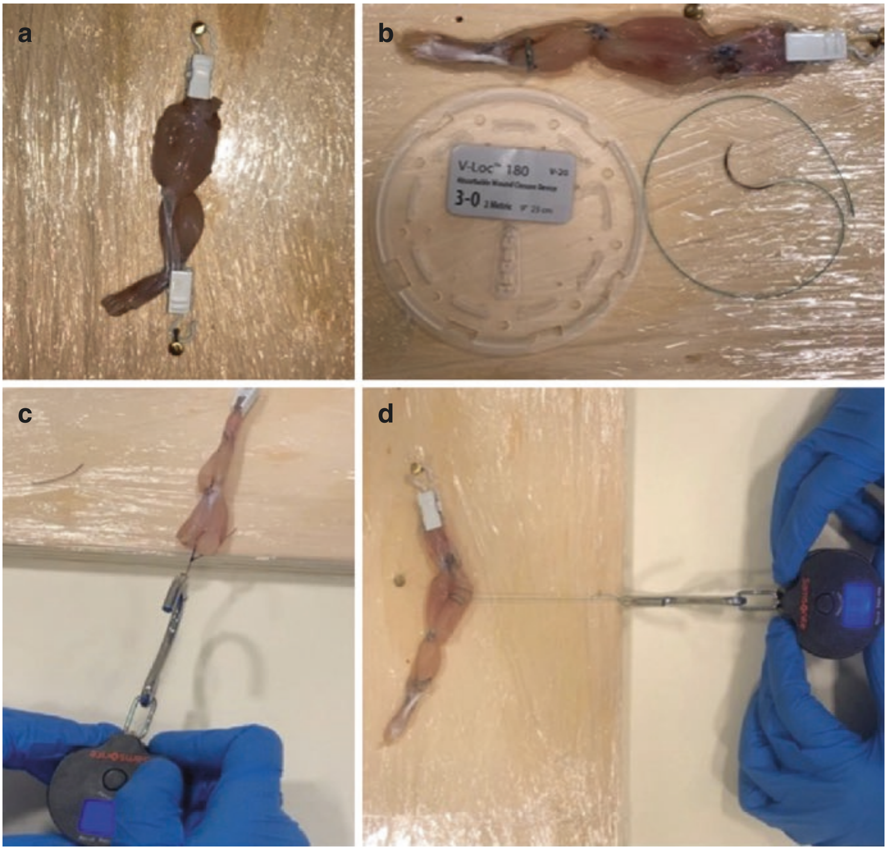

Fig. 14.13 (**a**–**d**) Schematization of the BioMechanical Study to simulate ESP and BRP using frog muscle

The weight relative to the force exerted to obtain muscle breakage in both surgical techniques was evaluated and analyzed.

These stress tests were performed several times for each procedure. Only the tests executed as described above were taken into consideration for the study results. The procedures that did not correctly simulate the surgical technique were excluded from the study.

A total of 20 stress test procedures were considered in this experimental study [21].

In ten cases an ESP simulation was performed and in the other ten cases a BRP simulation was made. Specimen muscle breakdown in the ESP simulation occurred with an average value of 0.7 kg of traction force (Standard Deviation = 0.258; High value = 1.20, Low value = 0.400 Median = 0.650 Average Absolute Deviation from Median = 0.200). Contrarily, specimen muscle breakdown in the BRP simulation

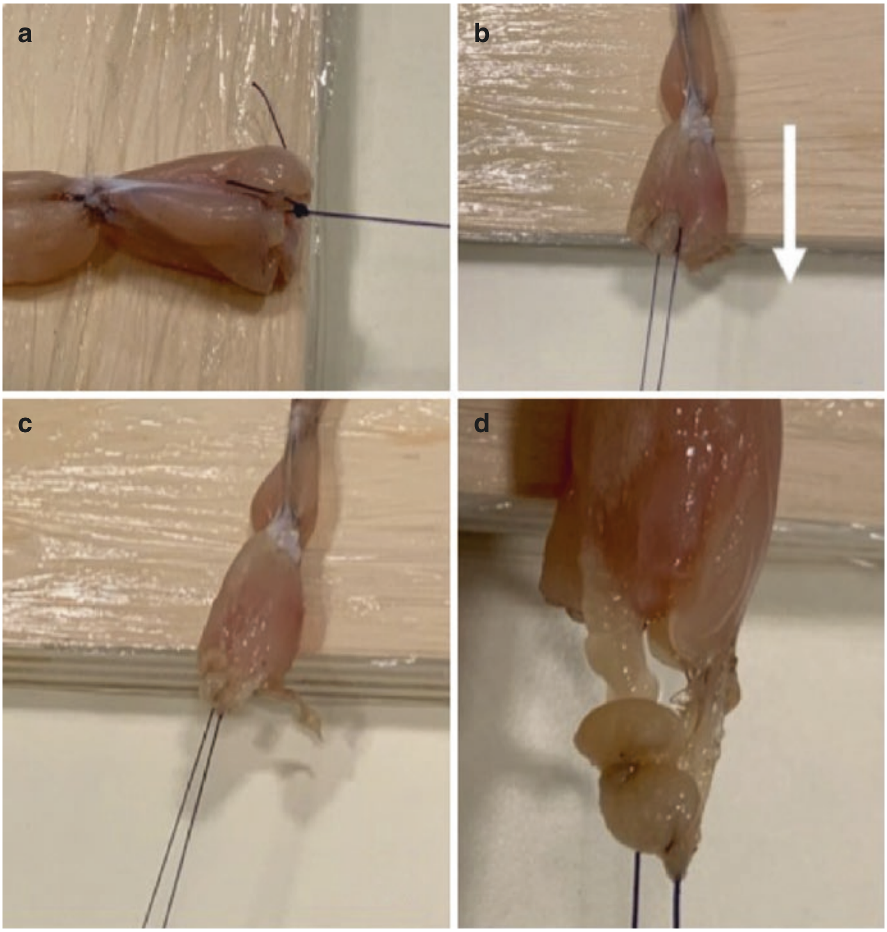

Fig. 14.14 Simulation of ESP technique, traction was performed with a vector having a longitudinal direction to the muscle fibers until muscle breakage was observed (**a**–**d**)

occurred with an average value of 1.38 kg of traction force (Standard Deviation = 0.297; High value = 1.80, Low value = 0.800; Median = 1.45; Average Absolute Deviation from Median = 0.220). A Statistical difference in the force resulted for the muscle breakdown between the two groups of tests emerged (Fig. 14.16; $p = 0.0001$).

Regression analysis didn't show any correlation between the muscle length and the value observed for muscle breaking in both groups of the study ($p > 0.5$ in both groups).

As shown by our stress test, the traction of the muscle with longitudinal vector (same direction as the muscle fibers) determines an elongation of the muscle fibers

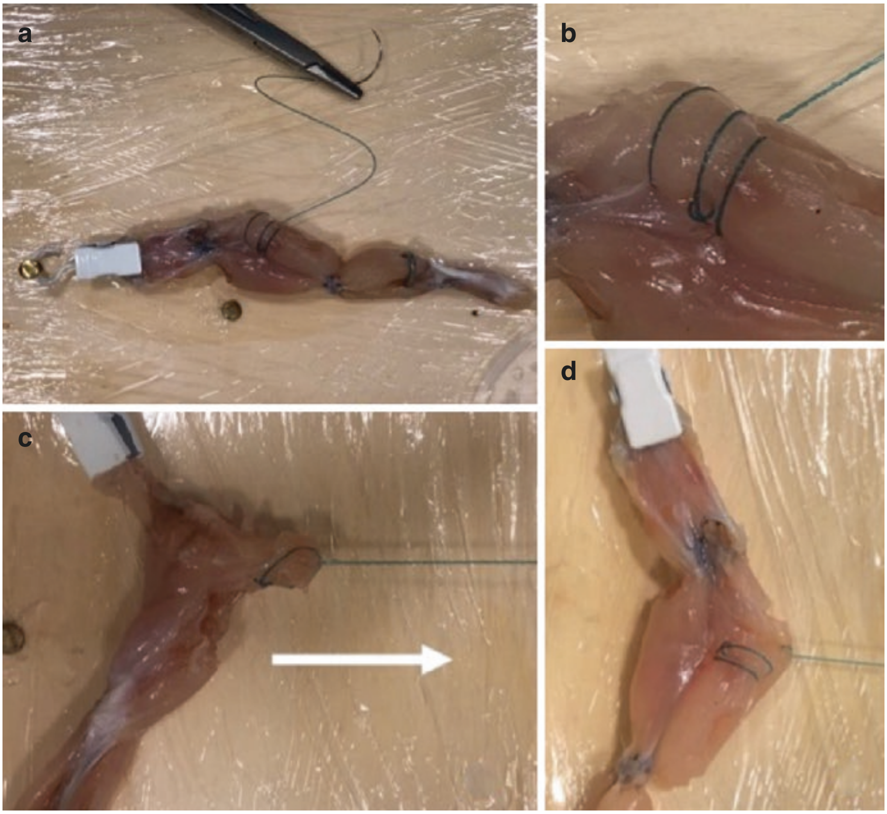

Fig. 14.15 Simulation of BRP technique Traction was performed with a vector perpendicular to the direction of the muscle fibers, until muscle breakage was observed (**a**–**d**)

with the possibility of breakage even at low tensile forces (average value 0.7 kg). Besides, in all the specimens tested the break occurred at the point of the suture's application.

In the BRP technique only a weakening of the inferior portion of the palatopharyngeal muscle is performed, and the traction is obtained with a vector having a perpendicular direction to that of the muscle fibers. As shown by our experimental stress test, when traction is exerted in a perpendicular direction to the muscle fibers, it is necessary to exert a greater traction force on the muscle before it stretches/breaks (average value 1.3). Therefore, in our opinion, the possibility of stretching/breaking of muscle fibers is lower using the BRP rather than the ESP technique [22, 23].

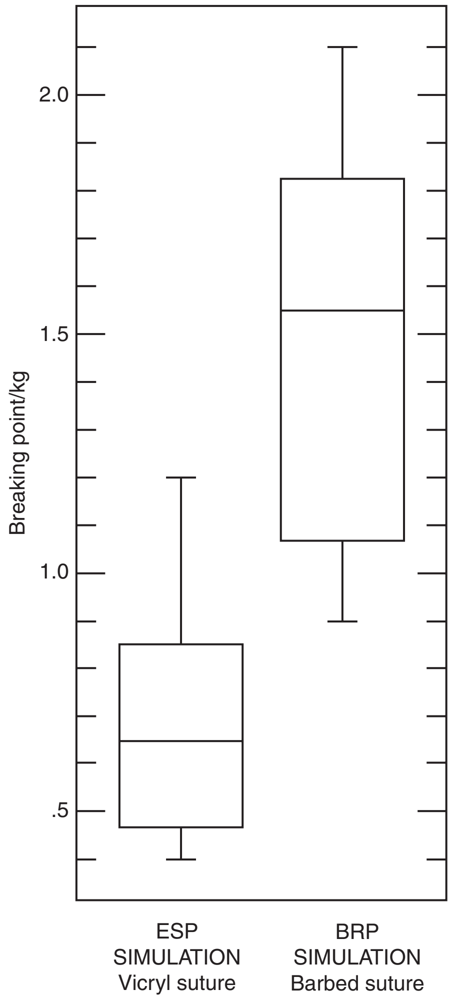

Fig. 14.16 Box plot showing differences between BRP and ESP in values of strength needed to obtain muscle breakdown ($p = 0.0001$)

14.5 Diffusion and Popularity

Last but not least, BRP was popularized in Italy and all over in the world. It received wide acceptance and in the spirit of the never-ending development many modifications were introduced by many smart colleagues, with sound results.

14.6 Conclusion

BRP is an innovative technique originating from a series of intuitions, experiments on cadaver, but also technological, biomechanical, and experimental studies on animal models, before its clinical application. Such technique is effective in improving respiratory outcomes of OSAS patients as confirmed by prospective multicenter and prospective randomized studies.

Acknowledgments We would like to mention here some of our visiting professors, fellows, and residents from different international and Italian universities and hospitals. We had the privilege to welcome all of them for stages of different durations (from days to years). Each of them gave us comments, suggestions, and criticisms which contributed to build up our idea and experience in BRP. Thanks to all of them for the invaluable amount of new contributions which made possible our project. There is a part of them in any BRP procedure.

Ahmad Mousa Alqudah—Jordan
Ahmed Ezzat Mohamed Saleh—Egypt
Ahmed Yassin Bahgat—Egypt
Al-Baharna Hussain—Saudi Arabia
Ana Isabel Costa—Portugal
Andres Ortega Traversaro—Chile
Angelo Eplite—Italy
Antonino Maiaci—Italy
Aysser Bassaly—Egypt
Chong Yaw Khian—Singapore
Cristina Penon Gonçalves—Brazil
Dipankar Datta—India
Domenico Modica—Italy
Erika Thaler—USA
Gianmarco Widmer—Swiss
Guillermo Plaza—Spain
Han Hong Juan—Singapore
Hayam Al-Taweel—Qatar
Hayfa Sulaiman Obeidat—Jordan
Heloisa Dos Santos—Brazil
Irene Álvarez García—Spain
Itzhak Braverman—Israel
Khai Beng Chong—Singapore
Lau Hung Tuan—Singapore
Maria Gabriela Bosco Morales—Spain
Maria Ines Saldanha—Portugal
Mariane Sayuri Yui—Brazil
Matej Delakorda—Slovenia
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Milena di Luca—Italy
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Pietro Abita—Italy
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Ranjit Gabriel Magherra—Singapore
Ranjith Venkitachalam,—Dubai

Robson Capasso—USA
Rodolfo Lugo—Mexico
Saleh Ali Al Ghamdi—Saudi Arabia
Samanta Dall'Agnese—Brazil
Sandeep Dachuri—India
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Sharmela Sondhi—India
Shirish Johari—Singapore
Soon Sue Rene—Singapore
Stanley Liu—USA
Sunil N. Khot—India
Susan K. Sebastian—India
Tay Hin Ngan—Singapore
Terry Tan Soon Heng—Singapore
Thong Kim Thye Mark—Singapore
Toh Song Tar—Singapore
Younes Muawya Bani—Jordan

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Candidates to Barbed Reposition Pharyngoplasty

15

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When all you have is a Hammer, everything looks like a Nail

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_15

15.1 Background

Barbed reposition pharyngoplasty (BRP) was devised as a palato-pharyngeal surgical procedure suitable for minimizing respiratory palatal flutter (palatal snoring) and for addressing palato-pharyngeal collapse in obstructive sleep apnea patients. BRP may be carried out as a single-level surgery or as a part of a multilevel surgical procedure, including transoral robotic surgery (TORS) for tongue base [1]. In our experience most of the patients went under this surgery after CPAP or mandibular advanced device (MAD) treatment drop out, but BRP may be also offered as a palatal revision surgery after UP3, LAUP, or ESP in case of failure. Besides, in an increasing number of cases, BRP is included in a multi-step treatment plan including MAD or positional devices (multimodal therapy) [2, 3].

The most common questions in sleep surgery are: "All patients are candidate to single-level velo-pharyngeal surgery?," "Is there a perfect palate procedure which may me applied for everybody?," "Is there a way for indicate to clinicians the best palate option in daily practice?," "Which patients are the best candidates for BRP surgery?"

In this chapter we discuss these aspects and provide useful information to select candidates to single-level velo-pharyngeal surgery as the BRP technique.

15.2 Barbed Reposition Pharyngoplasty for Sleep Apnea

When a patient suffering from PSG proven sleep apnea seeks your advice about a possible surgical procedure, and you consider performing a BRP technique, I suggest following a very simple but useful checklist. The basic concept is to try knowing in advance if your patient is fit for any kind of surgery, and, more importantly, if BRP technique could be sufficiently powerful for addressing the anatomical collapsibility of the patient's upper airways.

However, before offering any type of surgery, including BRP, don't forget to discuss any other alternative "anatomical" option (CPAP, weight loss, mandibula advanced devices, positional devices) disclosing into details advantages and disadvantages of each of them [4].

15.2.1 Selection Criteria According to Surrogate Endotypes (PALM Classification) (See Chap. 6 of Bosi et al. for a More Extensive Discussion)

Question #1: Is the Patient Fit for Surgery?

Pharyngeal anatomical collapsibility plays a central role in the pathogenesis of OSA. In fact, without any grade of pharyngeal collapsibility, obstructive events do not occur even if other non-anatomical pathophysiological factors are significantly altered [5]. The different conditions impacting on the likelihood for OSA

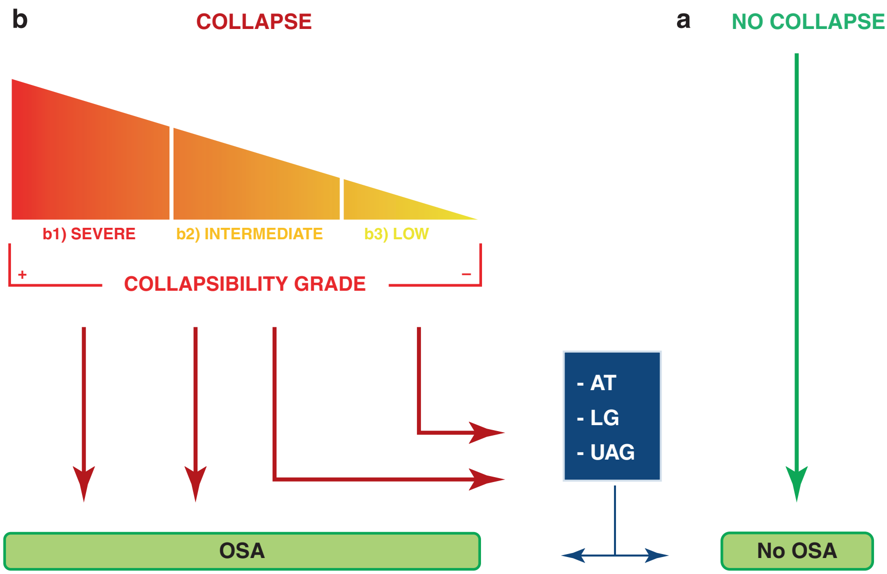

Fig. 15.1 (**a**) People without any grade of Upper Airways (UA) collapsibility do not develop OSA, even if other non-anatomical pathophysiological traits (PT) (Arousal Threshold [AT], Loop Gain [LG], Muscular Upper Airway Gain [UAG]) are abnormal. (**b**) (b1) Patients with severe UA collapsibility develop OSA, independent of any other non-anatomical PT. (b2) Patients with an intermediate grade of UA collapsibility develop OSA in relation to the pathologic grade of severity of the other non-anatomical PT (AT, LG, and UAG) or in relation with the grade of UA collapsibility severity. (b3) Patients with low UA collapsibility potentially develop OSA or not, only in the presence of other significant non-anatomical PTs

development are summarized in the following model Fig. 15.1: (a) People without any grade of Upper Airways (UA) collapsibility do not develop OSA, even if other non-anatomical pathophysiological traits (PT) (Arousal Threshold [AT], Loop Gain [LG], Muscular Upper Airway Gain[UAG]) are abnormal, (b1) Patients with severe UA collapsibility develop OSA, independently from any other non-anatomical PT. (b2) Patients with an intermediate grade of UA collapsibility develop OSA in relation to the pathologic grade of severity of the other non-anatomical PT (AT, LG, and UAG) or in relation to the grade of UA collapsibility severity. (b3) Patients with low UA collapsibility potentially develop OSA or not, only in the presence of other significant non-anatomical PTs [6, 7].

The passive Pcrit represents the main measure of anatomical collapsibility. On the other hand, the active Pcrit defines the anatomical collapsibility balanced by neuromuscular factors. Based on the passive Pcrit, it is possible to classify the anatomical collapsibility of the UA in the following way:

1. >2.5 cm H_2O—"High Collapsibility,"
2. >−2.5 and <+2.5 cm H_2O—"Intermediate Collapsibility,"
3. <−2.5 cm H_2O—"Low Collapsibility" [8, 9].

Recently, it has been proposed that the PALM classification, where “P” stands for Pcrit, “A” for AT, “L” for LG, and “M” for muscle recovery, can classify patients according to for PTs into three different subgroups. The PALM classification subgroups are as follows:

- PALM 1: This group involves about 23% of OSA patients and it is characterized by a high anatomical collapsibility (Pcrit higher than +2.5 cm H_2O). Weight loss, positional therapy, oral appliance (OA), CPAP, and upper airway surgery are the first line treatment as these treatments focus on anatomical factors (anatomical treatments).
- PALM 2: This is the largest subgroup and involves about 57% of patients with OSA; it is characterized by an intermediate collapsibility (Pcrit between +2.5 and 2.5 cm H_2O). These patients are potential candidates for anatomical treatments (subgroup 2a) or for a combination of anatomical and non-anatomical treatments (subgroup 2b).
- PALM 3: This subgroup involves approximately 19% of OSA patients with low collapsibility (Pcrit less than −2.5 cm H_2O), associated with abnormal non-anatomical PT. These patients are potential candidates for non-CPAP treatment options such as weight loss, OA, oxygen, and drugs which target the loop gain or the AT.

If we imagine to translate the described level of collapsibility into Eckert PALM Classification of endotypes [10], the situations described in Fig. 15.1 as b.3, b.2, and b1 may be defined, respectively, as PALM 3, 2, and 1. The condition labeled as “a” could be considered a normal situation of a not-OSA subject.

A somehow coarse but very practical stratification of OSA patients according to the PALM scale may be attempted applying a very simple schematization, with data immediately available from the polysomnographic test during the consultation in the medical office:

1. Apnea Hypopnea Index, from the sleep study, events/hour.
2. Effective CPAP pressure, from the ventilation device, cm H_2O.

Plotting AHI vs. CPAP value in different combinations, assuming that the cut-off of AHI is 40 and cut-off of CPAP is 8 cm H_2O is possible to implement a simple table easy at a glance. Therefore, using Table 15.1, we are able to locate our patient in one of the three possible endotypes areas of PALM (PALM 1, 2, or 3) classification [10].

Table 15.1 PALM classification according to AHI and CPAP values

Collapsibility	AHI	CPAP value	PALM classification
Less than −2.5 cm H_2O	<40	≤8 cm H_2O	PALM 3
Between −2.5 and +2.5 cm H_2O	<40	>8 cm H_2O	PALM 2
More than −2.5 cm H_2O	>49	>8 cm H_2O	PALM 1 or 2

The aim of surgery and of any other "anatomical therapy" (CPAP, weight loss, MAD, Positional) is to switch the value of Pcrit from a high pathological level to a normal level (no collapse).

In Fig. 15.2 the three red arrows are representative for three fully successful surgeries, with curative effect on patients with high, moderate, and low *p* critic.

In Fig. 15.3 are reported three cases of complete surgical failures, in which the tips of the arrows stop in a still pathological range of Pcrit, moving however, from initially severe to moderate OSA. The final degree of collapsibility is within the pathological range of moderate collapsibility.

In Fig. 15.4 is represented a special situation in which by the action less effective of surgical treated patients that originally PALM 1 or PALM 2 are turned into PALM 3 endotypes. Therefore, their situation has improved but not fully cured due to associated abnormal non-anatomical PTs (AT, LG, and UAG) [9].

These different situations of full success vs. complete surgical failures, or partial success or amelioration, are useful for introducing and making easier to understand the second key question.

Question #2 Is BRP sufficiently powerful for addressing the upper airways collapsibility of OSA patients? Is BRP able to change in a significant way the Pcrit value more than the threshold of −2.5 cm H_2O (PALM 1 and 2), and cure the OSA? So far, we don't have any direct measurement of the real action of BRP in lowering the Pcrit. No study is available with lab comparative measurements pre- and

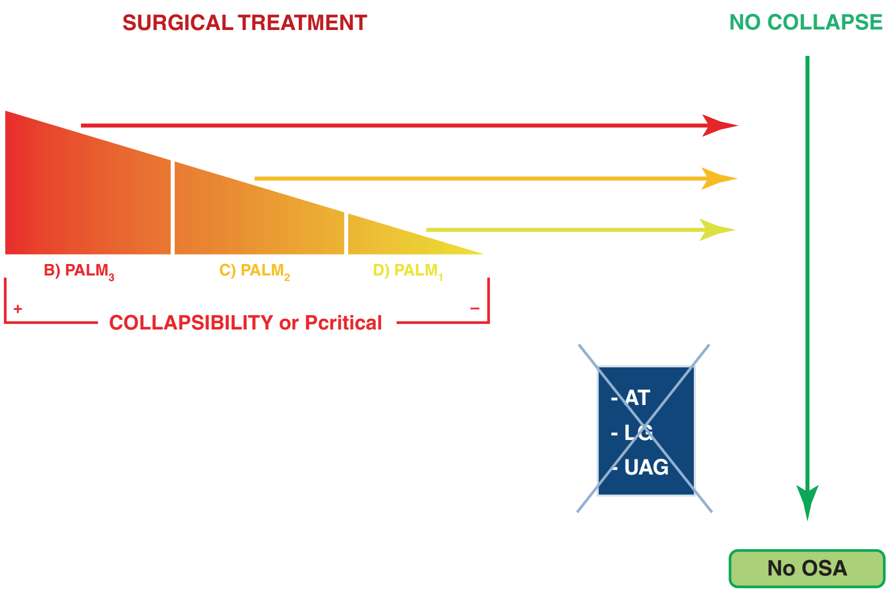

Fig. 15.2 The three red arrows are representative for three fully successful surgeries, with curative effect of patients with high, moderate, and low *p* critic

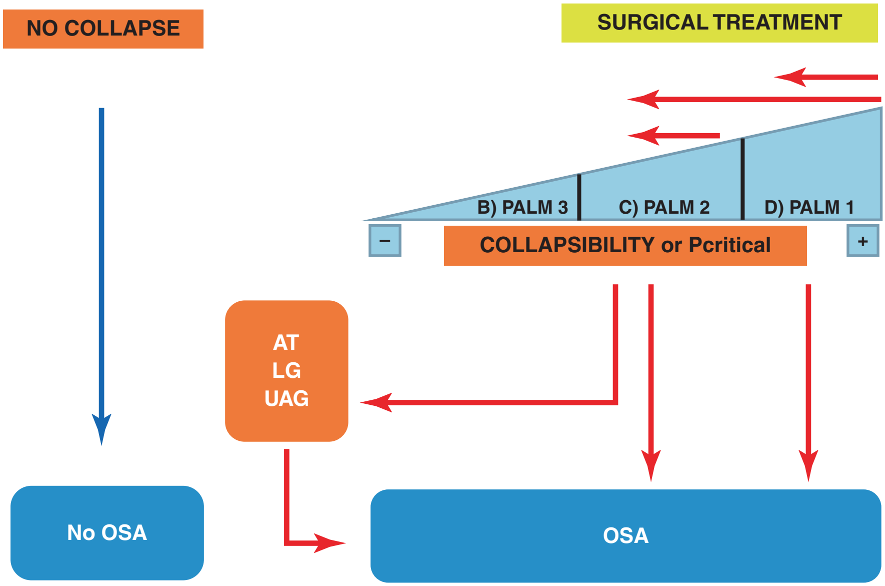

Fig. 15.3 In this picture, three cases of surgical failures are reported, in which the arrowheads stop in a still pathological range of Pcrit (or collapsibility), but passing from initially severe to moderate OSA

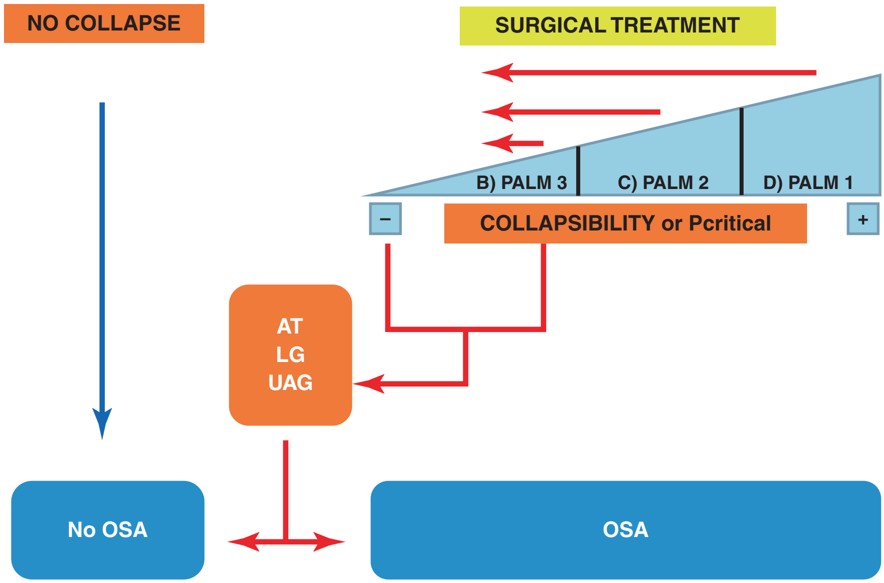

Fig. 15.4 In this picture is represented a special situation in which by the action less effective of surgical treated patients that originally PALM 1 or PALM 2 are transformed into PALM 3 endotypes. So are ameliorated but not really cured due to associated abnormal non-anatomical PTs (AT, LG, and UAG)

post-BRP. But we may have and indirect approximate estimation using at least a couple of data sets:

1. As reported in Bosi's chapter of this book, Schwartz et al. showed a significant decrease in passive Pcrit (from 0.2 ± 2.4 to −3.1 ± 5.4 cm H_2O, $p = 0.016$) after uvulopalatopharyngoplasty (UP3). It may be summarized in an average potential change between 4 and 6 cm H_2O.
2. In our hands BRP efficacy in terms of AHI reduction proved to be not inferior, and may be a little more effective than UPPP (Evolution of soft palate surgery techniques for obstructive sleep apnea patients: A comparative study for single-level palatal surgeries [5]).

According to these calculations it is possible to summarize:

In case of PALM 1 and PALM2 (high or intermediate anatomical collapsibility patients, respectively) BRP is probably effective as a standalone palate procedure and may be offered with a reasonable expectance of success. Patients with surgical failure could be those PALM 2 phenotypes with a combination of anatomical and non-anatomical PTs (AT, LG, and UAG).

In PALM 3 (patients with low collapsibility associated with abnormal non-anatomical PT) surgery could be poorly effective. It is mandatory to inform the patient that there is a real risk that an additional treatment will be required due to possible not anatomical endotypes. The three possible negative functional endotypes may be suspected if you have:

1. Low Arousal Threshold: AHI < 30, Hypopnea/Apnea > 60%, Nadir > 82.5%;
2. High Loop Gain: high proportion central/mixed apneas; positive Breath Hold Test;
3. Low Upper Airways Gain: flow limitation patterns in flow profile of PSG registration.

Concluding BRP may be considered as a standalone effective procedure for PALM1 and PALM 2 endotypes. In some PALM 2 and in PALM3 endotypes it is important to pay attention to the possible negative effects of not-favorable functional traits: low arousal threshold, high loop gain, and low muscle gain. In case of negative effects of not anatomical traits the BRP action in Pcrit reduction may be enhanced by additional surgical steps (multilevel surgery) or by prescribing MAD, positional or weight loss (multimodal therapy). For the same purposes drugs and myofunctional therapy are expected to play an increasing role in a near future for the selective treatment of negative functional traits (multimodal). Good anatomic-functional phenotypes (see below) are predictive of more important and effective reduction of Pcrit and will be discussed into detail in a dedicated paragraph of this chapter [10, 11].

15.2.2 Selection Criteria According to Anatomo-Functional Phenotypes

15.2.2.1 Barbed Reposition Pharyngoplasty for Sleep Apnea

BRP was developed in order to prevent retropalatal collapse in sleep apnea patients. It is well known that retropalatal collapse may be extremely different in different patients. The section of this segment of the upper airways is probably the most commonly affected in OSAS, with a wide variation in terms of shape and average section, reduced section or complete collapse during the breathing circle, and type or pattern of collapse. BRP aims to address significant collapse in two ways:

1. Increasing the average section of retropalatal area (nasal breathing) and oropharyngeal inlet (oral breathing).
2. Increasing the anterior and lateral wall stability to prevent inward collapse during the respiration [12, 13].

The oropharyngeal inlet is primarily enlarged by tonsillectomy, always necessary if not performed before. Bigger tonsils, wider air inlet after their removal. The coil of running barbed suture including palato-pharyngeal muscle posteriorly and pterygo-mandibular raphe antero-laterally is basically directed to displace palatine posterior pillar (palato-pharyngeal muscle) anteriorly and laterally toward the raphe, filling the space dissected free by tonsillectomy (if carried out) and supra tonsil fat pad always removed. This posterior pillar reposition increases the transversal dimension of the oropharyngeal inlet and at the same time it deepens the retropalatal space moving forward the soft palate (Fig. 15.5). Reposition is much more effective

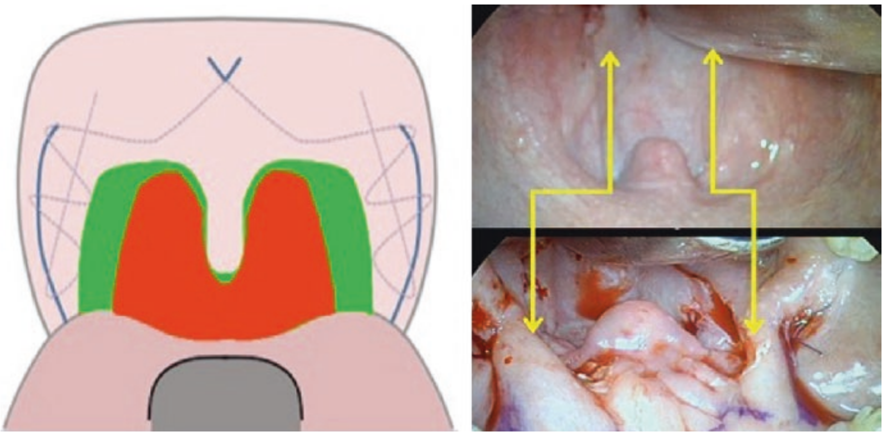

Fig. 15.5 The coil of running barbed suture including palato-pharyngeal muscle posteriorly and pterygo-mandibular raphe antero-laterally is basically directed to displace palatine posterior pillar (palato-pharyngeal muscle) anteriorly and laterally toward the raphe, filling the space dissected free by tonsillectomy. This posterior pillar reposition increase the transversal dimension of the oropharyngeal inlet and in the same time deepen the retropalatal space moving forward the soft palate

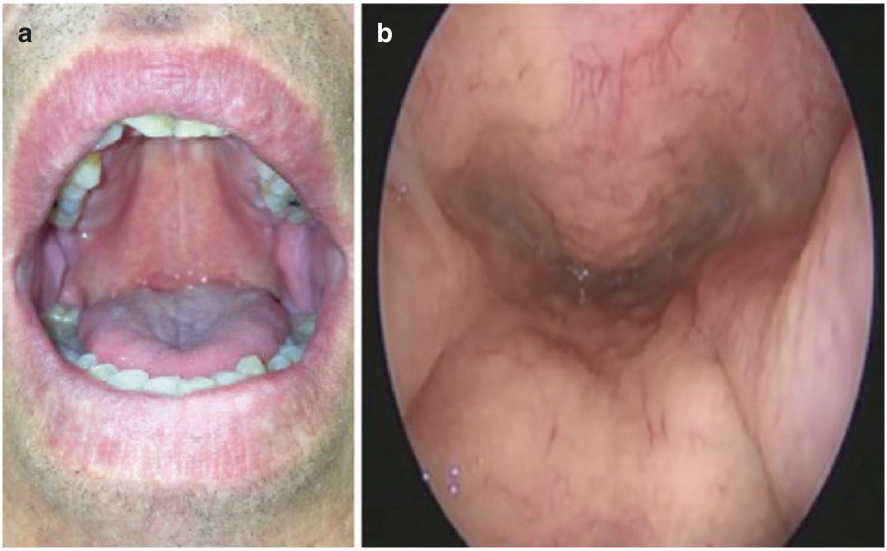

Fig. 15.6 Verticalized palate on which the BRP technique is less effective (**a**, **b**)

in oblique and intermediate palate according to Tucker Woodson. In case of vertical palates (Fig. 15.6a, b) with long hard palate the technique is by far less effective and a transpalatal advancement pharyngoplasty (TPA) should be put into account.

Besides this action in airways volumes, it seems to be much more important the action of stabilizing the anterior and lateral walls preventing inward collapse [14, 15].

Any palate requiring modification for preventing vibration/snoring and collapse/sleep apnea could be treated by BRP. However, different anatomical characteristics could identify good candidates to single-level velo-pharyngeal surgery. Table 15.1 summarizes the favorable and unfavorable characteristics and anatomo-functional factors of the patients who are considered good candidates for BRP for the treatment of OSA.

	Candidate to BRP	Clinical evidences
Old age	X	Probable non-anatomical factors underlying OSA
BMI > 35	X	Obese patients have multiple factors that cause OSA (accumulation of adipose tissue in the parapharyngeal regions, increased intrathoracic pressure, systemic inflammation)
		Weight loss should be considered before surgery
Positional OSA	√	Surgery stabilizing the pharyngeal lateral wall could further reduce the number of apneas in the lateral position, benefiting patients with this phenotype
Retrognatic/ micrognatic patients	X	Probable collapse of the oral tongue, hypopharyngeal obstruction, and/or secondary palate obstruction
Big tonsils (grade III or IV)	√	Increase of the space of the oropharyngeal region, reduction of collapse of the extravelic tonsils during sleep
Figure 15.7		

	Candidate to BRP	Clinical evidences
Macroglossia	X	Probable collapse of the oral tongue, hypopharyngeal obstruction, and/or secondary palate obstruction
Figure 15.8		
Tongue base hypertrophy (Friedman grade 3 or 4)	X/√	Probable hypopharyngeal obstruction and/or secondary epiglottis collapse
Figure 15.9		Consider multilevel surgery with base of tongue/ hypopharyngeal surgery
Vertical palates (Tucker Woodson classification)	X/√	According to the evidence of Tucker Woodson classification very vertical palates have a single-level velo-pharyngeal surgery than horizontal or intermediate palates
Figure 15.6		Consider TPA (transpalatal advanced surgery)
Thick lateral pharyngeal walls	√	Better possibility to have a good palato-pharyngeal muscle relocation; Greater possibility of stabilizing the lateral pharyngeal walls. Muscle release strongly recommended
Figure 15.10		
Floppy and usually thin palate	X/√	Possibility of breaking the muscle fibers with less increase of the velo-pharynx space
Figure 15.11		Consider implementing UPF (uvulo palatal flap)
Circular Velo-pharyngeal collapse at Muller maneuver	√	BRP offers the possibility to increase the antero-posterior retro-velar space and stabilize the lateral walls reducing the transversal collapse.
Figure 15.12		
Lower inter-incisive distance	X	Inability to perform adequate exposure of the oropharyngeal cavity and perform the BRP surgical technique
Figure 15.13		
Distance between hyoid bone mandible more than 2.5 cm	X	High probability of tongue collapse and secondary palate obstruction. Studies suggest a higher tongue is less stable and tends to a more antero-posterior collapse
Figure 15.14		

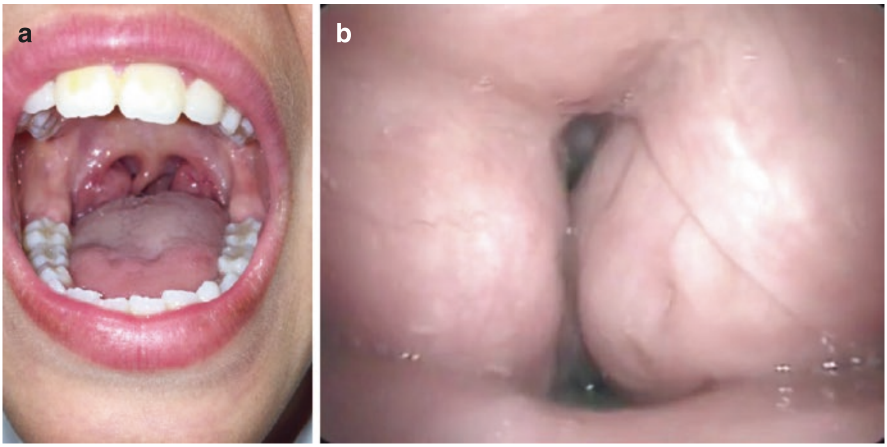

Fig. 15.7 III degree (**a**) or IV degree (**b**) of palatine tonsillar hypertrophy

Fig. 15.8 Example of macroglossia in which an unusual volumetric growth of the tongue is appreciated, often related to endocrinological diseases

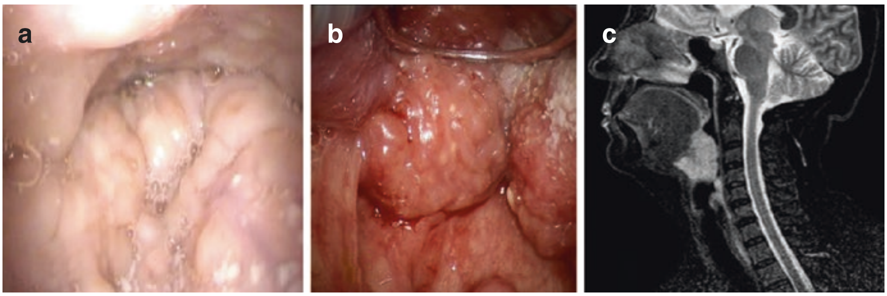

Fig. 15.9 (**a**–**c**) IV degree lingual tonsil hypertrophy in which the laryngeal vestibule cannot be appreciated

Fig. 15.10 Thick lateral pharyngeal walls with reduced distance between the palatine pillars

15.2.2.2 Barbed Reposition Pharyngoplasty for Simple Snoring

BRP may be considered for any patient suffering from simple snoring (if unwilling to put into account wait and see, to try MAD and to undergo palate RFVR in local anesthesia), if you are reasonably convinced after a complete conventional examination that palate flutter is the main responsible of his snoring condition. It's very common but it is not always true. You must be aware that in a few cases additional anatomical sites may act as secondary or tertiary sources of vibration [16, 17]. According to your workplace policy for sleep endoscopy diagnostic use (if applied

Fig. 15.11 Floppy and usually thin palate

to everybody vs. only in selected cases), you don't have any problem if you widely apply DISE. In case of more strict selection rules for DISE, put into account that snoring may be produced in more than one site, and not only in the palate[12]. Thus, keep in mind that BRP was devised to dampen the vibration arising from the soft palate (uvula excluded) and to some extent from the upper lateral pharyngeal wall. From the anatomical and functional point of view keep in mind that the riskiest palate for snoring is a long, thin, and floppy palate with elongated uvula combined with a reduced retropalate section [18]. Here some of the most common anatomical situation encountered in the treatment of simple snoring and the corresponding

Fig. 15.12 Muller's maneuver: after a forced expiration, an attempt at inspiration is made with closed mouth and nose, whereby the negative pressure in the chest and lungs is made very subatmospheric; so we can appreciate the VADS collapsibility

Fig. 15.13 Lower inter-incisive distance which doesn't allow transoral surgical approaches

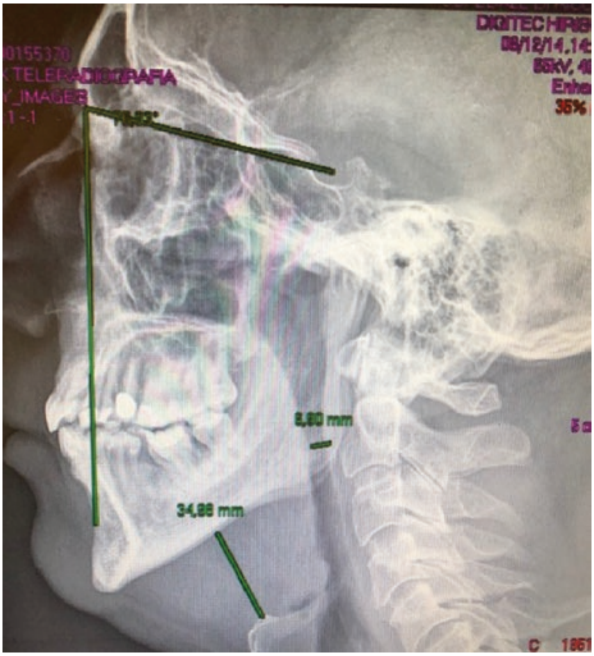

Fig. 15.14 Example of distance between hyoid bone and mandible 2.5 cm

maneuvers to address the pathology. Keep in mind that generally snoring probability is related mainly to the length of soft palate (including uvula), to the floppiness (opposite to rigidity) of the soft palate, and to the velocity and turbulence of the retropalatal airflow through a narrow space.

1. A long palate (distance between posterior spine and free edge) (Fig. 15.15). Few the classical palatoplasties do includes a step of palate shortening. In UP3 the palate is directly trimmed, in LAUP scarring retract the tissues, in UPF the uvula pushes the palate up. In BRP the superiorly based "V shaped" course of the

Fig. 15.15 A long palate (distance between posterior spine and free edge greater than 2 cm)

Fig. 15.16 Example of elongated uvula

suture is devised to suspend and to some extent to shorten and tighten the soft palate. The shortening is anyway minimal and additional steps as midline crossing sutures are commonly recommended.

2. An elongated uvula is frequently encountered. Basically, BRP includes a minimal trimming of the prolapsed mucosal tip and a sort of "CAPSO" maneuver at the base of the uvula in order to dampen the traveling wave of vibration (Fig. 15.16) [19].
3. Floppy and usually thin palate: usually thin palates tend to be less rigid, and more prone to produce vibration induced by the air flow along the superior surface, especially in case of turbulent and or high-speed flow. BRP acts basically increasing the tension and rigidity of the soft palate pulling out the insertions

Fig. 15.17 Example of anterior-posterior palatal collapse

around the palate (like a drum skin stretched from the casing). Two more additional tricks may be suggested in order to increase the palate rigidity. More commonly a midline crossing suture may offer a simple internal scaffold. Otherwise, in case of very thin palate and slim uvula, an additional Uvulo Palatal Flap according to Stanford may be an additional option Fig. 15.15 [20, 21].

4. A posteriorly collapsed palate (flat pharynx) or a funnel shape retropalatal area. Both situations contribute to produce a turbulent and high velocity airflow. The management of this condition is described below (Fig. 15.17) [22, 23].

15.2.3 Selection Criteria According to Drug-Induced Sleep Endoscopy Findings

Barbed pharyngoplasties are usually performed as a single-level surgery, which means that only the velo-oropharyngeal structures are remodeled to increase the oropharyngeal space and stabilize the pharyngeal lateral walls. In these patients, selection and choice of surgical procedure for OSA, was traditionally relied on static awake examination. This investigation could not accurately predict sites of obstruction during the sleeping state. Awake upper airway endoscopy can be done safely in the office setting; it is useful for evaluating any anatomic variants of the upper airway structures such as deviated nasal septum, turbinate hypertrophy and adenotonsillar hypertrophy as well as for ruling out pathological obstruction such as nasal polyps and tumors. Tonsils grade, Friedman palate position and Friedman lingual tonsil grade have been considered useful scores for identifying patients in whom single level velo-pharyngeal surgery should be avoided. Nevertheless, awake upper airway assessment is less useful for predicting the dynamic upper airway soft tissue collapse that occurs during sleep and may not identify some important sites of obstruction/collapse [24, 25].

Fig. 15.18 Sleep endoscopy setting

To better identify the loci of obstruction, a specific examination called drug-induced sleep endoscopy has been proposed in the last years. DISE is a safe and practical technique for evaluating dynamic upper airway collapse during a drug-induced simulation of sleep (Fig. 15.18) [26].

DISE has been defined as superior to awake fibro-laryngoscopy in identifying sites of obstruction and collapse patterns of OSA patients. As shown by Soares et al., there is a significant difference between DISE and awake fiber-optic nasal endoscopy with Müller's maneuver in the identification of hypopharyngeal/base of tongue collapse. The incidence of severe retrolingual collapse identified via DISE was 84.9% compared to 35.8% via awake fiber optic evaluation ($p < 0.0001$) [27]. Yegïn et al. themselves, comparing DISE and Müller's maneuver for diagnosing the site of obstruction, observed that there was no statistically significant concordance between these two examinations regarding antero-posterior collapse of the tongue (23.8%) and epiglottis (42.9%) [28].

DISE evaluation makes possible to identify whether obstruction at the base of the tongue, hypopharynx and the epiglottis/larynx or more sites of obstruction/collapse are presents during sleep and if they play a significant role in OSA pathogenesis.

Single-level velo-pharyngeal surgery may not have the desired therapeutic effects if there are more sites of obstruction than the velo-pharyngeal one, such as an obstruction of the base region of the tongue, hypopharynx or epiglottis [29, 30].

Therefore, as indicated by De Vito et al. in the European position paper on drug-induced sleep endoscopy, DISE could be useful for guiding clinicians in the choice of the best surgical treatment; if during DISE only a velar and oropharyngeal obstruction is identified, a single-level pharyngoplasty surgery is usually indicated [31].

Table 15.2 Comparation of Group A and B regarding delta-AHI, delta-ODI, delta-LOS, and success rate

	Group A	Group B	*p*
	BRB without preoperative DISE	BRP with preoperative DISE	*t*-student test
Delta-AHI	−12.4 ± 11.4	−19.2 ± 10.5	**0.003**
Delta-ODI	−12.6 ± 10.4	−19.6 ± 11.2	**0.004**
Delta-LOS	−4.82 ± 9.54	−7.42 ± 8.21	0.15
Success rate (AHI < 20 and 50% improvement in AHI)	30/50 (60%)	41/50 (82%)	Chi-square test
			0.02

Different authors have proposed DISE as a useful tool in preoperative OSA surgical planning, identifying which patients are good candidates for single-level surgery and patients who require multilevel surgery[32]. Gillespie et al. compared the surgical planning based on the Muller maneuver with that based on DISE and found that in 62% of cases the surgical plans had been modified after DISE evaluation, due to its results. Similarly, a systemic review of eight studies and 535 OSA patients revealed that surgical planning is modified by preoperative DISE evaluation in 50.2% of cases [33].

In our recent clinical study, we have compared 50 patients who underwent BRP without a preoperative DISE evaluation (Group A) and 42 patients (Group B) treated with BRP surgery but preoperatively selected by means of a preoperative DISE. In this second group of patients, after DISE evaluation, 70% of patients were selected for single-level BRP surgery because they showed an isolated velo-pharyngeal collapse at the DISE evaluation, without obstruction at other upper airway levels evaluated. Table 15.2 reported the results of the prospective study mentioned above.

Both groups of patients showed a statistically significant difference between preoperative and postoperative values of AHI, ODI, and LOS ($p < 0.05$ in all cases). Comparing Group A and Group B patients, the therapeutic success rate was found to be 60% in patients treated without preoperative DISE evaluation and 83% in patients treated with preoperative DISE ($p = 0.02$) [12].

15.3 Conclusion

Selection of candidates to a single-level velo-pharyngeal surgery is not easy. This must take into consideration the phenotypic characteristics of the patients (sex, age, BMI, etc.) and precise anatomical criteria. Awake upper airways (UA) endoscopy helps to define most of the anatomical criteria and it is mandatory in the preoperative evaluation of patients enrolled for barbed reposition pharyngoplasty. However, the evaluation of patients in static conditions alone may not highlight the real anatomical sites of collapse/obstruction [34].

DISE is a useful tool for investigating the UA of patients with OSA in order to improve the selection of patients for surgery and to identify the best surgical procedure according to sites and patterns of collapse. Besides, it would seem to improve the surgical results of single-level velo-pharyngeal surgery owing to the possibility of excluding patients with obstruction of the base of the tongue, hypopharynx and the epiglottis/larynx [35].

In accordance with that stated by Kezirian et al., we believe that DISE is not a magical panacea. DISE is an evaluation technique that must be performed properly, with findings that must be interpreted in the light of other clinical characteristics (age, BMI, sex, anatomical findings including tonsil size) in an effort to improve surgical results. Even after treating all the areas of collapse and improving the UA lumen, there is still no guarantee of success. A 360-degree view of the patient is mandatory and the physiological traits underlying the UA collapse and OSA (loop gain, arousal threshold, and muscle response) must not be underestimated [36].

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Barbed Reposition Pharyngoplasty (BRP): Surgical Technique

16

Claudio Vicini and Giannicola Iannella

"Make it easy"

16.1 Barbed Reposition Pharyngoplasty (BRP): Surgical Technique

BRP is routinely performed in general anesthesia with orotracheal intubation (armored tube) in order to allow a single-step nose procedure if required. Nose procedure is usually done after BRP (possible posterior nosebleed after previous nose surgery could be disturbing).

Patient is positioned in supine position with a pillow or an inflatable balloon under the shoulders (head extended). Face is draped leaving nose and mouth uncovered. Surgeon sits at the head Fig. 16.1.

A Storz Crowe Davis mouth-gag with a wide and hollow blade is placed and suspended to a lifting Mayo stand. A plastic cheek retractor is also routinely used to make wider the oral opening and protect oral commissure Fig. 16.2a, b. It proved to

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_16

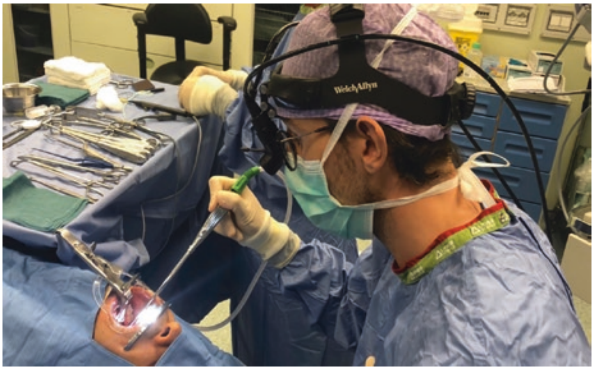

Fig. 16.1 Patient and surgeon's position in BRP surgery

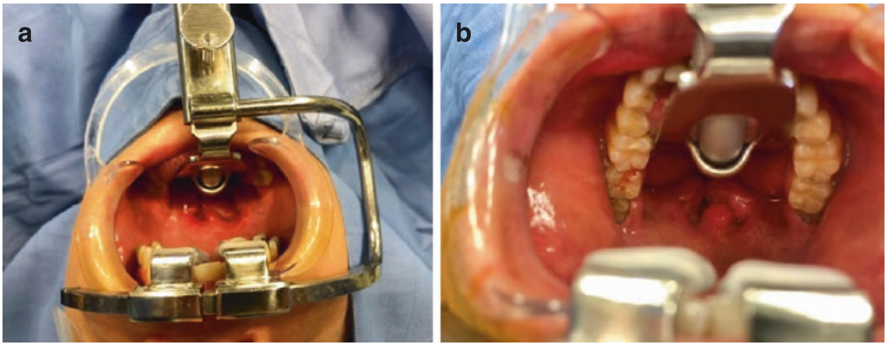

Fig. 16.2 Oropharyngeal explosion; A Storz Crowe Davis mouthgag with a wide and hollow blade is placed and suspended to a lifting Mayo stand. A plastic cheek retractor is also used to make wider the oral opening and protect oral commissure (**a**, **b**)

be very useful for teaching, providing to the students standing beside the surgeon a wider view of the surgical field.

A conventional headlamp may be used, but I prefer to magnify and intensely illuminate the field with an alogen Zeiss loupe 2.5× [1, 2].

For research, documentation or teaching purposes, 3D Storz exo or endoscopes proved to be useful. In this case the surgeon may operate throughout the entire procedure by looking at the screen wearing the 3D goggles (Fig. 16.3a, b). It takes a minimal training time, but it seems really promising. In the future it is likely that most of the palate surgery will be performed watching a screen rather than looking directly inside the mouth.

Xylocaine is sprayed onto the oropharyngeal surface in order to reduce post op pain. Regardless to their size, tonsils are removed as first surgical step (Fig. 16.4). The reason is to get access to the palato-pharyngeal muscle, a key structure for BRP. Moreover, tonsillectomy is a great help for clearing pharyngeal airways in case of big tonsils.

Despite each surgeon's preferred technique (cold instruments, Bowie, bipolar, coblator, etc.), the procedure is a "mucosa and muscle sparing" one. A redundant

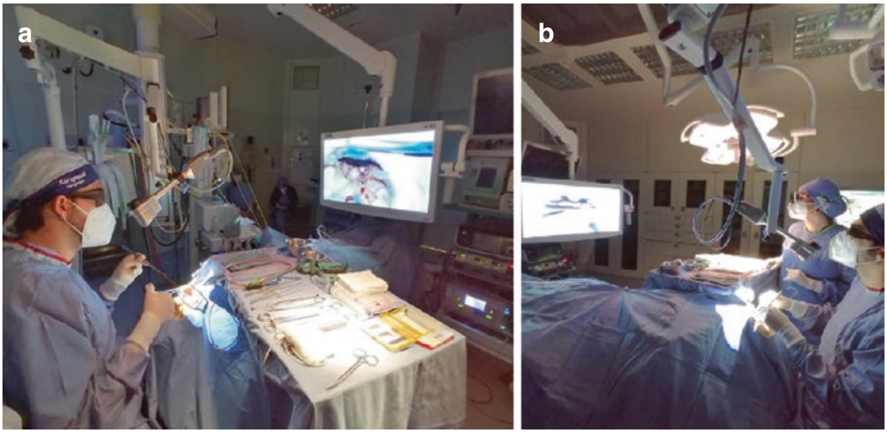

Fig. 16.3 3D visualization system, using Karl Storz exoscope (Vitom®) (**a**, **b**)

Fig. 16.4 Oropharyngeal view after tonsillectomy

mucosa will drape completely the underlying muscle, preventing scar retraction and stenosis. These complications are more common if muscles are left bared. After tonsillectomy a gauze soaked with local anesthetic is placed in the tonsil bed to reduce post op pain. The empty tonsil fossa will allow an easier anterior and lateral repositioning of the palato-pharyngeal muscle closer to the palato-glosso muscle, reducing the risk of postero-medial relapse.

A schematization of the BRP surgical technique is reported in Fig. 16.5a–d.

The real first step of BRP (after tonsillectomy) is to mark a horizontal line tangential to the top of tonsil bed. A second vertical line tangential to the lateral limit of the tonsil fossa is marked up to the first horizontal one (Fig. 16.5). Within the angle between these lines, mucosa and underneath tissues are removed deeply, including supra-tonsil fat, fibrous tissue, and minor salivary glands (Fig. 16.6a–c). A gentle traction of the specimen by a small-tip Kelly forceps may allow the surgeon to remove much more deep tissue than expected, with minimal mucosal sacrifice ("around the corner" dissection). It is the only "resective" step of BRP. Few

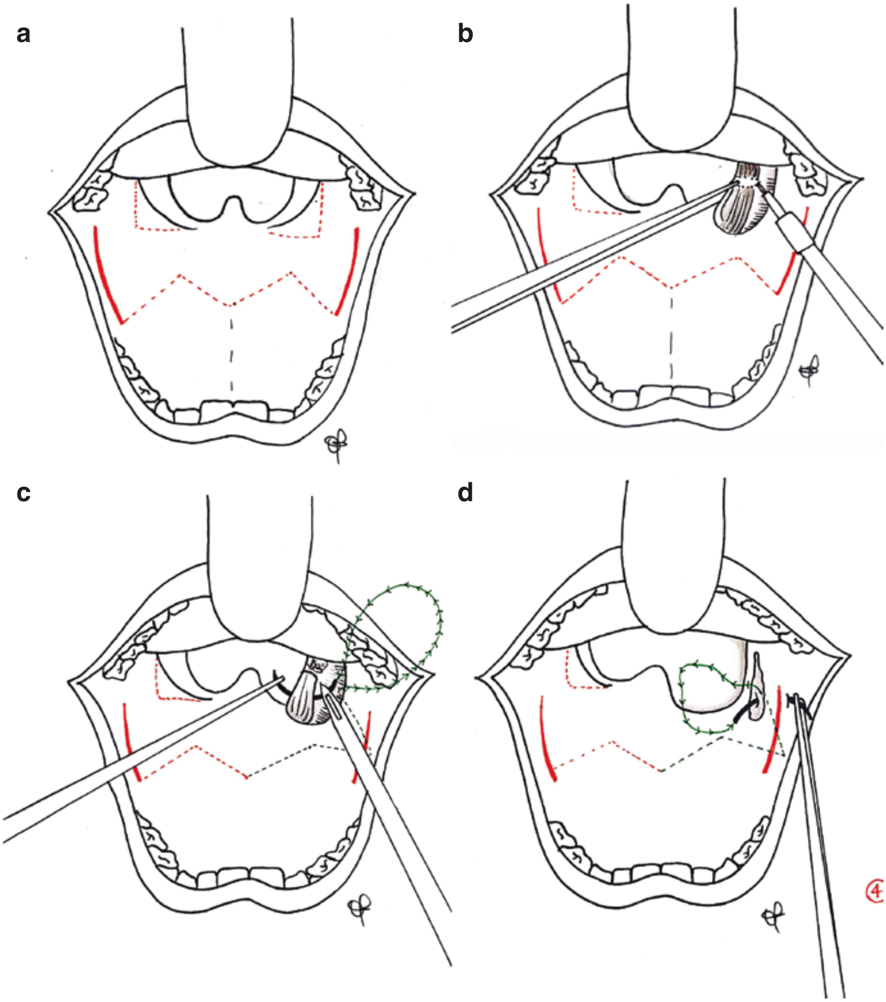

Fig. 16.5 Schematized view of the barbed reposition pharyngoplasty (BRP). (**a**) Velo-pharyngeal landmarks of the BRP. The dashed lines of the supra-tonsillar region indicate the tissue that must be removed, while the dashed lines of the soft palate indicate the initial course of the barbed suture. The lateral continuous red line indicates the pterygomandibular raphe. (**b**) Partial transection of the palato-pharyngeal muscle in its inferior portion. (**c**) The barbed suture after moved from the soft palate to the raphe and the supra-tonsillar region is used to anchor the dissected pharyngeal palate muscle; (**d**) The barbed and the pharyngeal palate muscle suture are moved towards the raphe with an increase in the posterior and lateral oropharyngeal space

millimeters of mucosa and few milligrams of muscle, fat and minor salivary glands are removed. It is a minimally invasive maneuver, but quite useful to stabilize the palato-pharyngeal muscle's superior part and to reduce the risk of its displacement. Moreover, the new squared oropharyngeal inlet allows an increased airflow, without shortening the midline soft palate, therefore preventing possible VPI [3–7].

Fig. 16.6 Surgical view; the first step of BRP is to mark a horizontal line tangential to the top of tonsil bed; a second vertical line tangential to the lateral limit of the tonsil fossa is marked up to the first horizontal one

The second step is the partial trans-section of the palato-pharyngeal muscle in its inferior part, close to the tongue (Fig. 16.7). The preferred cutting tool in our hands is a Needle Tip Bovie (e.g.: "Colorado"), producing a sharp and bloodless cut. The depth of the cut is defined step by step with a gentle and progressive deepening of the cutting tip. Through forceps we will check the progressive reduction of the tension and a sufficient release of the posterior pillar. The goal is to be able to easily superimpose posterior pillars to the anterior ones without significant tension. Bipolar coagulation is frequently necessary to control bleeding points along the procedure.

In tonsillectomized patients, an upper based triangular mucosectomy is the first step (Fig. 16.8a, b). In this case the key structure to expose is the fibrous and muscular thread produced by the post tonsillectomy scarring and fusion of palato-pharyngeal and palato-glosso muscles. This fibro-muscular structure is managed in the same way as palato-pharyngeal muscle in not-tonsillectomized subjects, with progressive and targeted release.

No further tissue cutting or resection is required. Therefore, BRP is considered a minimally invasive technique [4–7].

The next steps of the technique (its "core business") are based on the generation of superior, lateral, and anterior pulling and repositioning vectors from the palato-pharyngeal muscle toward the pterigo-mandibular raphe, by means of anchoring barbed sutures loops.

The anterior vector of traction increases antero-posterior distance between soft palate and posterior pharyngeal wall. The lateral vectors widen the transversal diameter of the oropharyngeal inlet. Finally, the supero-lateral vectors shorten the soft palate and "steal" the superior third of the vertical leg of the palato-pharyngeal muscle and integrate it into the lateral side of the palate free edge, contributing to the widening of the oropharyngeal inlet.

Beside the 3D anatomical volume increasing action of the technique, the most important functional effect is to increase the lateral wall rigidity, splinting it, and preventing inward collapse. If necessary (very floppy palate), a midline running sutures crossing the soft palate midline is applied to stiffen the floppy palate tissue dampening vibration and reducing snoring.

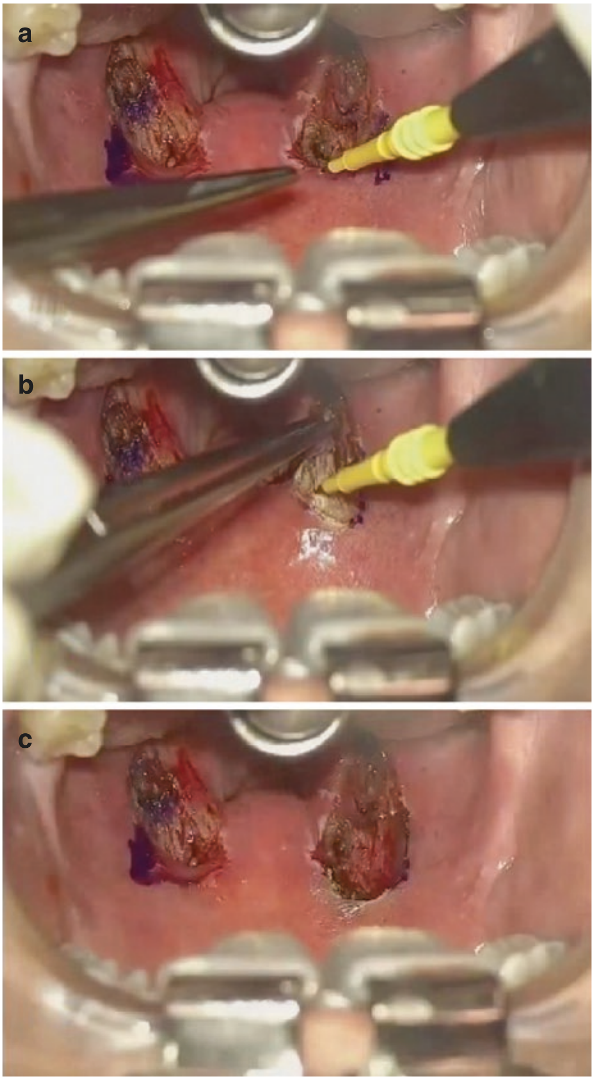

Fig. 16.7 Surgical view; within the angle between the lines mucosa and underneath tissues are removed in the depth, including supra-tonsil fat, fibrous tissue, and minor salivary glands (**a**–**c**)

All the above-described goals are obtained by means of a single bidirectional barbed running suture. Bidirectional means that barbs orientation are reversed in the midline of the thread, inverting the direction of the grip. The rationale of this bidirectional array is that each side stabilize the other side without the need of a final blocking knot [1–7].

After many trials with different types of sutures, our current decision is the Medtronic V-Loc 180, 2–3/0, taper needle 1/2 26 mm, thread of 23 cm, green (Fig. 16.9a, b).

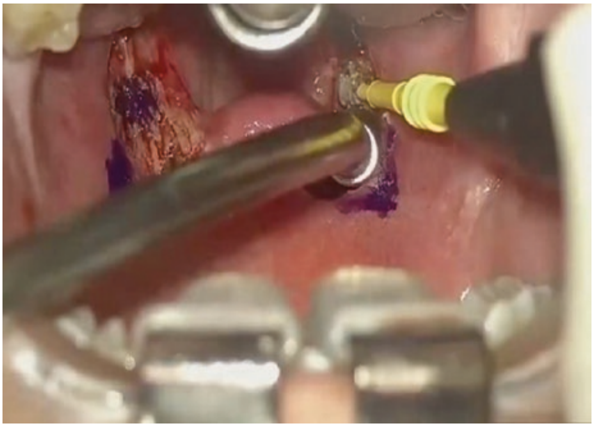

Fig. 16.8 Surgical view; partial transection of the palato-pharyngeal muscle in its inferior aspect

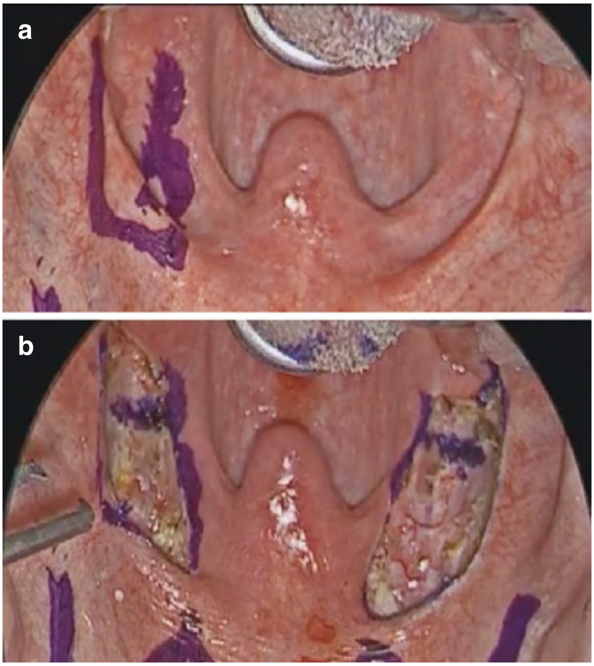

Fig. 16.9 Surgical view; in tonsillectomized patients, an upper based triangular mucosectomy is realized and palato-pharyngeal muscle is identified and sectioned (**a**, **b**)

Some remarks about our choice [4–10]:

a. This suture is available only as monodirectional suture. Joining the end of a couple of monodirectional threads a single bidirectional suture is easily provided (Fig. 16.10).
b. V-Loc proved to be sufficiently soft and flexible with less foreign body sensation inside a such mobile structure as the soft palate; on the other hand the structure (length and angle) of the barbs and their 3D array gives us a stronger grip in the muscle.

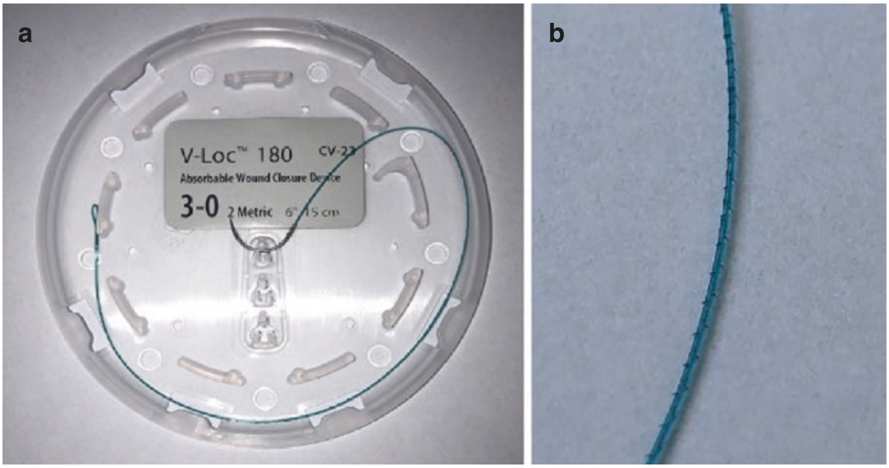

Fig. 16.10 Barbed suture used in our experience: Medtronic V-Loc 180, 3/0, taper needle 1/2 26 mm, thread of 23 cm, green (**a**, **b**)

c. 180 is more stable and long-lasting than 90.
d. 2/O or 3/O thread thickness are sufficient to fit to the different types of palates to treat.
e. Taper needle tip is "a must." A conic needle just spread away the tissues and let them to go back with their elastic recoil and tightly stabilizing the barbs. A cutting tip could compromise the elastic return.
f. A 26 mm needle is the best compromise for working. In the wide soft palate area, it allows just a couple of passages to reach the raphe. In the deeper and narrow tonsil bed area it is sufficiently small to be freely moved.
g. The available thread length of 23 cm is sufficient to finalize the entire suture.

Before starting to suture we use to mark tree main landmarks (pen or cautery) (Fig. 16.11a):

1. The posterior nasal spine in the midline, easy to locate along the midline at the junction between hard and soft palate
2. The pterigo-mandibular raphe of both sides, located by digital palpation or by means of a blunt instrument
3. The intermediate point located along a para-sagittal line drown exactly between nasal spine and raphe. In long palates the point is lower, in short palates the point is higher. In this way BRP may be customized to the single case anatomy.
4. The landmarks are joined by broken lines depicting a "w" shaped pathway.

Barbed running suture is better performed by means of a bold needle driver with a squared jaw (it is a Maxillo-facial tool devised for managing metal wires). The strong bite of the needle driver prevents possible needle rotations during the suturing.

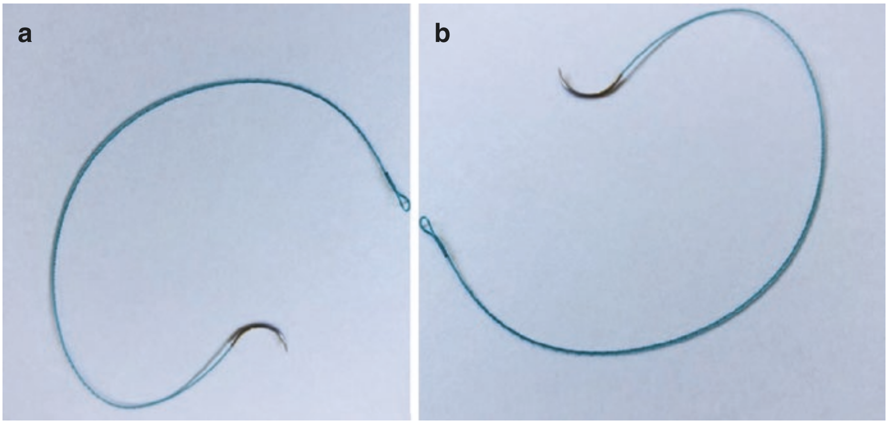

Fig. 16.11 Joining the end of a couple of monodirectional threads a single bidirectional suture is realized (**a**) first suture (**b**) second suture that will be anchored to the previous one

The basic rule of barbed suture is just one, but it is somehow difficult to learn by most of the rookie surgeons: in order to keep the thread completely submucosal the needle must always re-enter into the same hole where it came out from. A completely buried suture is more comfortable for the patient and usually is reabsorbed in a longer time. Magnification and a meticulous suction of any minimal bleeding proved to be very useful in order to allow the surgeon to enter exactly where required.

The common starting point for the running sutures of both sides is the soft palate area around the posterior nasal spine. It may be injected with a vasoconstrictor and incised producing a small slit to accommodate the relatively bulky knot joining the two monodirectional sutures.

For the first needle passage and for the next steps passage in the area of the soft palate the needle is held at its end, close to the thread. It made possible to achieve a longer tunneling before to get out from the mucosa. In this way two passages are always sufficient to reach pterigo-mandibolar raphe. Working with shorter needles three passages may be required. Usually at the beginning we approach the right side of the palate [3–5].

The first passage of the needle starts from the posterior nasal spine slit and aims laterally to the intermediate point (Fig. 16.11b, c). The right hand is usually used. The needle is kept in a deep plane ideally inside the muscle, far from the oral mucosa and far from the posterior surface of the soft palate. The tip of the needle is finally extracted from the intermediate point, usually with no or minimal bleeding. Second step: the needle, firmly held at its end, is exactly introduced into the same hole from where it was extracted and pointed laterally to the raphe, moving again inside the muscle plane (Fig. 16.11d, e). The left hand is preferred. Usually, it emerges close to the cheek mucosa not far from the Stensen duct opening. Both may be inadvertently hit by the sharp tip of the needle. In cases of long palate after this passage a gentle traction of the thread may be helpful for reducing the height of the palate.

The third step is carried out by the left hand entering the same hole and passing the needle through the palate muscle until the apex of tonsil fossa. So far, the suture is pre-planned by the mucosal landmarks (Fig. 16.11f).

The next two steps are of capital importance. The palato-pharyngeal muscle runs as a Romanic arch from the pharyngeal wall inferiority to the uvula superiorly. The needle must be introduced, from lateral to medial, posterior to the palato-pharyngeal muscle bundle, most commonly at the junction between the superior third and the inferior two thirds, using the right hand (Fig. 16.12a, b). The needle is extracted close to the medial limit of the bare tonsil fossa, at the level of the transition line between muscle and the intact pharyngeal mucosa. This passage proved to be easier holding the needle at its center. A second loop of suture may be passed according to the surgeon preferences with the same rules (Fig. 16.12c, d). It seems to give more stability for the next traction.

Afterward, it follows another major step. The technique requires a passage back lateral to the raphe, and the application of the proper tension to the suture in order

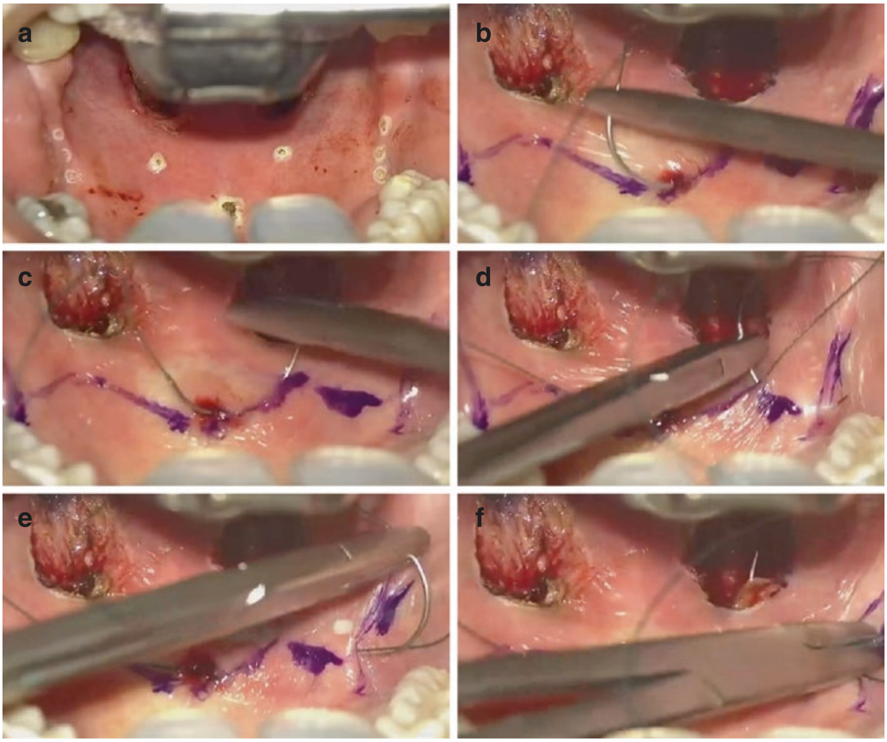

Fig. 16.12 Surgical view; the three main landmarks: The posterior nasal spine in the midline, the pterigo-mandibular raphe of both sides, the intermediate point located along a para-sagittal line drown exactly between nasal spine and raphe (**a**). The first passage of the needle starts from the posterior nasal spine slit and points to the intermediate point (**b**, **c**). Second step: the needle is exactly introduced into the same hole from where was extracted and pointed lateral to the raphe (**d**, **e**). The third step is carried out by the left hand entering the same hole and passing the needle through the palate muscle till the apex of tonsil fossa (**f**)

to reposition the palato-pharyngeal muscle more lateral and more anterior, and to splint and tighten the lateral wall (Fig. 16.12e, f). That is the key of the entire BRP [6–10]. Some additional remarks:

1. proper tension was experimentally measured in a very precise way (Fig. 16.12f), but it is unpractical to transfer the physical data to the surgical routine. It is just a matter of sensibility and experience, with few simple rules;
2. pull gently the thread in a progressive way and follow the contemporary movement of the posterior pillar toward the anterior one, till the pillars meet (Fig. 16.13a). It's enough. More tension is not necessary.

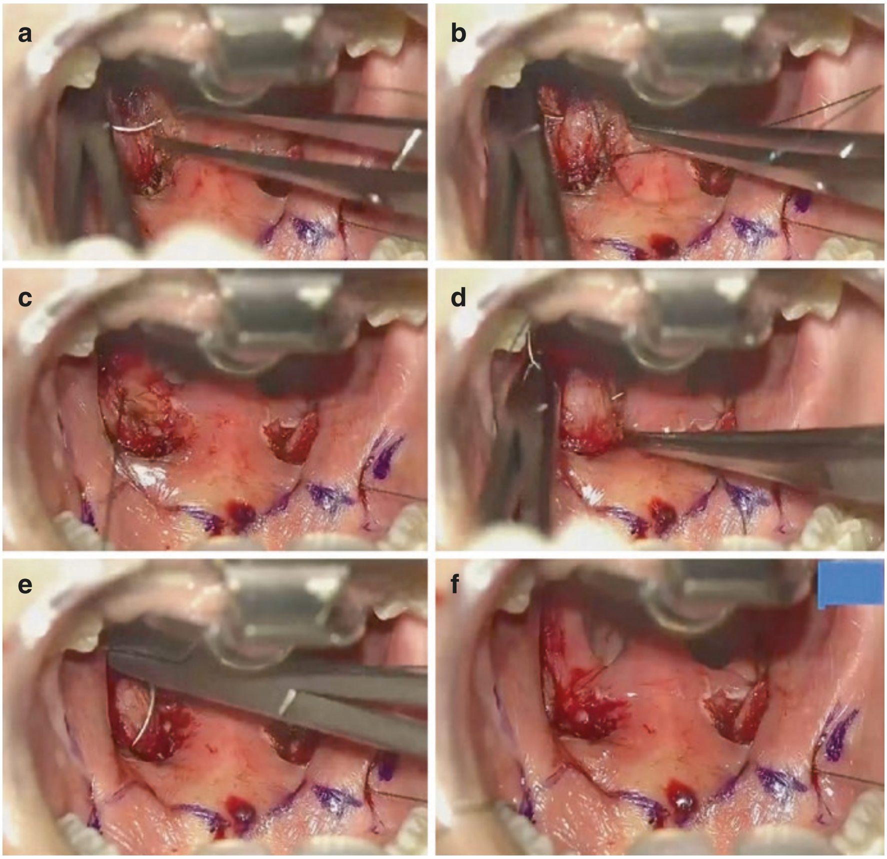

Fig. 16.13 Surgical view; The needle must be introduced, lateral to medial, posterior to the palato-pharyngeal muscle bundle most commonly at the junction between the superior third and the inferior two thirds, using the right hand (**a**, **b**). A second loop of suture may be passed according to the surgeon preferences with the same rules to give more stability for the next traction (**c**, **d**). The technique requires a passage back lateral to the raphe, and the application of the proper tension to the suture in order to reposition the palato-pharyngeal muscle more lateral and more anterior, and to splint and tighten the lateral wall (**e**, **f**)

3. avoid over-tension! If you pull too much, it will be impossible to go back and release the created tension. Over-tension may induce muscle strangulation and ischemia, with late tissue breakdown and relapse with functional failure. It also increases post op pain.
4. check for one more possible complication of over-tension, a possible rise of a transversal mucous ridge in the posterior pharyngeal wall. It may be the beginning of a progressive postoperative pharyngeal webbing and stenosis, a complication very difficult to address. It's much better to prevent ridging simply avoiding over-tension. But if a minimal ridge should appear, try to push down by gently pressure and "massage" by a gauze. Usually, it works in a sufficient way to prevent significant troubles [7–10].

Now it's time to switch to the other side (Fig. 16.13b). It's formally wrong to completely finalize one side and then to take care of the other one. The trick is to proceed parallelly, skipping from one side to the other many times in a progressive way. Our goal is to get the best balance between right and left side, with the final best symmetry as possible. It's the same principle which guides us in tighten wheel bolts when we change the wheel.

On the left side the steps are identical to the right side. According to the surgeon preference for each single step the right or the left hand may be used. Ambidexterity may be very useful.

How many loops of suture are required to get the goal of a more stable pharyngeal wall, a cleared airway and a less vibrating palate? There is no final answer for this crucial question. Single surgeon expertise plays a major role. But some simple suggestions are possible. First, try to use the entire length of the suture thread, don't waste any millimeter: each contributes with many barbs. Many loops proved to be better than few: it's logic and scientifically proved. Any single case deserve its special treatment according to its special combination of needs: how much to increase the lumen, how to change the shape, how to stiffen the pharyngeal wall and the palate. In our hand about 4 to 5 loops for each side proved to be sufficient and possible with a 23 cm thread, including the crossing sutures if required. Working in the anterior soft palate area, splinting the lateral pharyngeal wall, combining these steps in different ways, manipulating the uvula, BRP by itself may include into a single procedure many surgical actions described in a wide spectrum of different specific surgeries: ESP, Lateral Pharyngoplasty, UPF, pillar procedure, Anterior

Pharyngoplasty, Uvuloplasty. Not many pre-planned techniques for different situations, but just one customizable technique which can be fit for all the altered anatomies to address: one fits all [6–10].

Finally, two more additional technical points. The uvula management and the Midline Crossing Sutures technique.

If uvula is considered within the average limits, it is completely untouched. If the uvula seems to be elongated, it may be trimmed up to a normal length. In case of very thin palate the uvula may be flipped up to the palate and sutured to it. It's a sort of Uvulo Palatal Flap and it may contribute to dampen palate vibration and snoring.

Two more tricks for very floppy palates.

Sometimes it is possible to remove an ellipse of mucosa at the base of uvula and to suture the gap. It proved to be useful for reducing the snoring wave.

A second option is to run a transversal set of sutures (usually 3 or 4) from one raphe to the contralateral one, crossing the midline. It produces a suture/ fibrous scaffold at the center of the soft palate contributing to its rigidity (Fig. 16.13c–f).

At the end of the BRP two additional suggestions:

1. Don't hesitate to apply some simple interrupted stiches if required in case of small residual mucosal gaps.
2. Do inject the peripheral areas of the surgical field with long acting local anesthetics.

The last step of BRP, despite the previous suture routes, is to pass the needle back to the soft palate. Then the thread is gently pulled out and cut by a scissor. The tip of the thread is retracted back and disappears inside the palate. Despite the angulation of this last leg of the running suture, it's advisable to provide a long suture leg. As you know in a running suture its stability relies upon the stability of the two ends of the suture, traditionally knots in not barbed sutures. In BRP the final long leg was devised to produce a firm blocked end of the suture, offering more stability to the overall suture array [6–10].

The overall time required to perform a complete BRP may be estimated around an average of 45 min, excluding time for tonsillectomy [10] (Fig. 16.14).

Schematization of final view of the velo-pharyngeal region after BRP surgery is showed in Fig. 16.15. Increase of lateral and antero-posterior space and more stability of lateral pharyngeal walls are obtained.

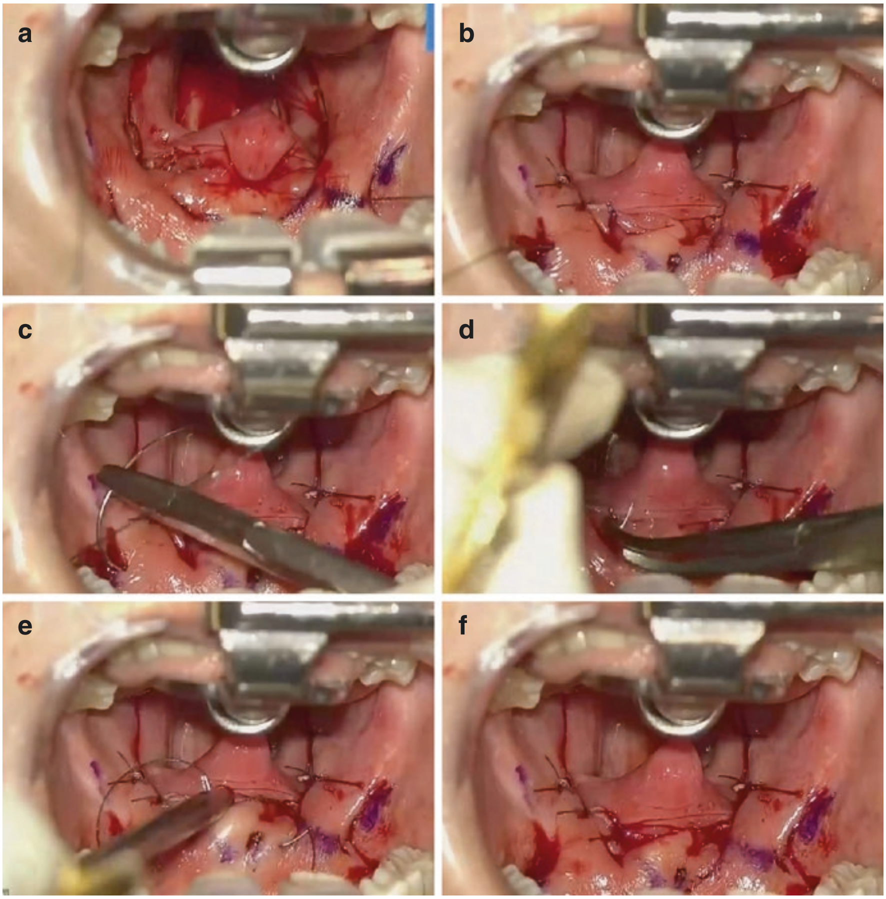

Fig. 16.14 Surgical view; It's necessary to pull gently the thread in a progressive way and follow the contemporary movement of the posterior pillar toward the anterior one, until the pillars meet (**a**). The same steps are made in the other side (**b**). An option is to run a transversal set of sutures (usually 3 or 4) from one raphe to the contralateral one, crossing the midline. It produces a suture/fibrous scaffold at the center of the soft palate contributing to its rigidity (**c**–**f**)

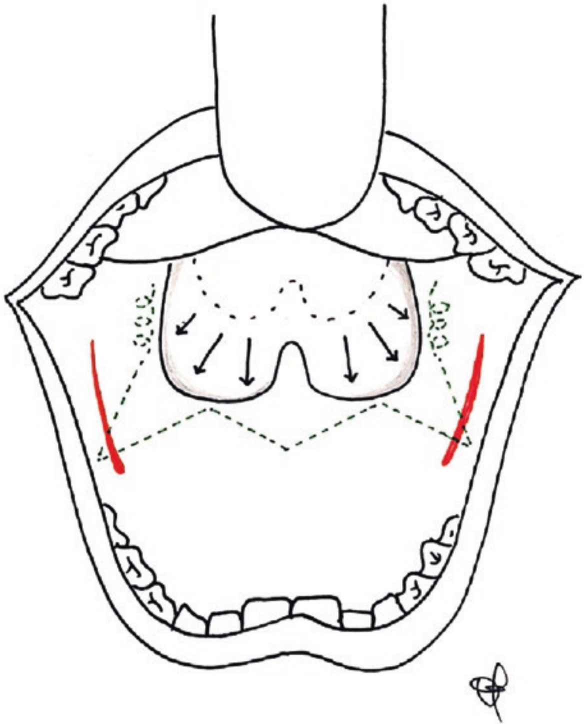

Fig. 16.15 Schematized view. Final result after BRP surgery showing relocation towards the pterygomandibular raphe of the palato-pharyngeal muscle; increase of the lateral and antero-posterior velo-pharyngeal space (arrows)

Acknowledgments We would like to thank Dr. Anna Bonsembiante for the realization of the surgical technique iconography.

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Barbed Reposition Pharyngoplasty (BRP): Postoperative Management, Outcomes Evaluation, and Follow-Up

17

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17.1 Postoperative Management of Barbed Reposition Pharyngoplasty

The postoperative management of sleep apnea patients in our department can be summarized as follows:

- According to SIAARTI guidelines the patient should be admitted to a recovery room for a semiintensive monitoring in the immediate early postoperative. Supplemental oxygen in the PACU is gradually decreased until the patient is able to maintain adequate oxygenation in room air when left unstimulated. Patients who desaturate when left undisturbed should either remain in the PACU or be monitored by continuous pulse oximetry when transferred to the ENT ward [1, 2].
- Because the supine position worsens upper airway collapsibility and lung functions it is prudent to maintain postoperative OSA patients in semi-upright posi-

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_17

tion for the first 24 h and during the hospitalization. The upright position may also help to reduce rostral fluid shift and therefore decrease postoperative airway obstruction, and so the patient is also stimulated to obtain an upright position earlier and walk in the first postoperative day.

- The use of opioids for postoperative pain management should be used cautiously due to the associated respiratory suppression in sleep apnea patients. In order to control upper airway patency and edema a short course of infusion of steroids may be helpful. Our routinely analgesia is scheduled with paracetamol 1 g TID and 48 h continuous morphine 20 mg + ondansetron 8 mg in elastomer. Sleep apnea' patients may benefit from a restrictive or specific strategy for perioperative fluid therapy, especially fluids with relatively lower salt content (i.e., Ringer's Lactate) rather than normal saline solution [3].
- The patient should follow a specific soft diet for 2 weeks, starting on the first day after surgery with an ice cream diet.
- The median postoperative stay at hospital was 4 days.
- The first postoperative visit is scheduled 2 weeks after surgery.
- A repeat home sleep Apnea study (HST) is requested routinely at 3 to 6 months postoperatively.

Our perioperative management is focused in reducing the risk of postoperative morbidity, reducing pain and to achieve a fast-feeding recovery of the patient.

In the last 200 patients who underwent Barbed Pharyngoplasty (from January 2019 to April 2021), the median stay in hospital was four days (range 2–14 days). Dexamethasone was administered in 32% of the patients to reduce pharyngeal edema during perioperative period. During hospital stay or at home 56 patients had antibiotic therapy (31.6%).

All the patients have full recovery of normal feeding [4, 5].

Figure 17.1 shows velo-pharyngeal aspect at first day post-BRP surgery.

Fig. 17.1 Oropharynx view 2 days after BRP surgery

17.2 Outcomes Evaluation and Follow-Up

The patients receiving pharyngoplasty generally have high expectations about the success of the surgery, especially in the immediate future. However, the post-surgical course is long, as the healing is largely due to secondary intention and due to the development of an adequate scarring tissues that allows the anatomical

Fig. 17.2 Oropharynx view 20 days after BRP surgery

remodeling given by the technique to be sustained for a long time. In our experience, the first outpatient visit is usually done after 15–21 postoperative days (Fig. 17.2) and after 3-months post-surgery (Fig. 17.3) [6, 7].

The visit will focus on dysphagic and/or painful problems, the patient will be given a POPS questionnaire, the points at greatest risk of thread extrusion will be assessed (tonsillar fossa, anterior pillar, raphe). If a small section of the thread is

Fig. 17.3 Final oropharynx view 3 months after BRP surgery

visible, it is necessary to ask the patient if he complains of stinging pain; in that case it is recommended to remove only the smallest extruded part. If nasal procedures have been performed, nasal cleaning will be performed with/without removal of eventual nasal splints. In the event that a robotic procedure was associated, it is advisable to perform a fibroscopy in order to assess the healing status of the BOT and the tracheostoma site will be medicated and, in case of dehiscence, sutured. In our clinical practice, we will re-evaluate the patient, from a functional point of view, 6–12 months after surgery [8, 9].

17.3 Postoperative Pain and Swallowing

Pain management is carefully evaluated during the first postoperative visit. In fact, despite the correct healing, often patients may still complain of some degree of pain upon swallowing or sudden painful episodes, generally intense but of short duration. This symptomatic set, although debilitating and psychologically tiring, often decreases and disappears within 3 months. Therefore, it is important and necessary to illustrate the probable course in order to reassure the patient and to help him in the management of pain [10]. In our hands, the drugs most used in pain management are paracetamol associated with codeine and ketoprofen. If the symptoms are occasional and not associated with swallowing, the use of the paracetamol-codeine combination is relegated to need. If the painful symptom is still continuous and/or associated with swallowing, then the administration will be 500 mg of paracetamol and 30 mg of codeine every 8 h to be preferred half an hour before main meals to relieve swallowing. The use of ketoprofen will be recommended only if in the interval between paracetamol/codeine administrations the pain is aggravated with a single dose dosage of 50/100 mg and a maximum daily dose of 200 mg. The use of hyaluronic acid-based solution and/or mouthwashes is strongly recommended even several times a day. In case of extrusion of the thread or areas of infection near the sutures, it is important to remove the thread as little as necessary in order to alleviate the discomfort but at the same time, to not affect the outcome of the surgery [11, 12].

Another important aspect is to evaluate the dysphagia/swallowing problem if it exists and identify the foods that should temporarily not avoided. In this way we will try to identify the correct diet and the progressive reacquisition of a free diet [9]. After evaluating these aspects and their correct healing, it has to be illustrated to the patient the course of the following months, trying to mitigate their symptoms with adequate therapy that could affect the quality of life, and giving the possibility of an easy access for re-evaluation if any discomfort or problem arises [13].

17.4 Respiratory Outcomes Evaluation

A complete polysomnographic examination is generally recommended to be performed around 6–12 months after the surgery [14, 15].

The response criteria that we used are based on the scientific literature and on epidemiologic data of OSA-related morbidity and mortality. A reduction of at least 50% in AHI is generally used to define a good response to treatment. Furthermore, the parameter CT90 could be considered a physiologic factor because this variable reflects the alert response to oxygen desaturation, which involves arousal threshold and respiratory function. Moreover, CT90 values less than 1 might be considered as an index of successful response to surgical treatment as well as lowest saturation

($LoSaO_2$) above 85% [16]. Unlike the common consideration, no significant correlation between tonsil size and the success rate of the surgery are evident, but a statistically significant predictor of good surgical outcome includes BMI, with a mean value of 29.4 ± 4.8 kg/m^2 in those successfully treated and of 34.8 ± 5.5 kg/m^2 in those not successfully treated [17, 18].

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Barbed Reposition Pharyngoplasty (BRP): Intraoperative and Postoperative Complications

18

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18.1 Intraoperative and Postoperative Complications

Despite the significant reduction in morbidity guaranteed by this innovative technique, barbed reposition pharyngoplasty (BRP) can lead to certain intraoperative and postoperative complications [1].

18.1.1 Intraoperative Complications [2–5]

- Suture rupture: intraoperative rupture of the barbed suture is possible, especially when bleedings around the thread requiring cauterization occur. In case of a rupture, due to the intrinsic structure and function of the barbed suture technology (self-locking and resorbable), the thread should be left in place and the surgeon should restart the procedure with a new barbed suture.

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*, https://doi.org/10.1007/978-3-030-96169-5_18

- Suture loop (uses a syringe guide to pull the suture out).
- Hemorrhage might occur during surgery or in the postoperative period in about 1-5% of cases, especially during the tonsillectomy surgical step. Moreover, the manipulation of the palatopharyngeal muscle may lead to an increased risk of bleeding caused by a potential lesion of the tonsillar artery or of the ascending palatine artery. These events can be usually controlled by means of bipolar cauterization and/or hemostatic ligations. In our experience, avoiding anticoagulants, NSAIDs, and ASA when not strictly necessary allows minimizing the incidence of intra- and postoperative bleedings.
- Dental injuries are possible in all transoral surgical techniques in which it is necessary to position a mouth gag. Therefore the surgeon must always be careful regarding the teeth and aware of any unstable dental elements, possibly using silicone protections on the upper dental arch.

18.1.2 Postoperative Complications [6–10]

- Barbed suture extrusion is a possible event during the postoperative period. Nevertheless, a recent study from our group retrospectively demonstrated that it does not affect in a negative way subjective and PSG outcomes [6]. (For details, see the specific chapter)
- Swallowing impairment. Short-term postoperative deglutition impairment is frequent, and it is mainly adduced to postoperative pain with consequent antalgic limitation of the meso-hypopharyngeal muscles activity. Prolonged dysphagia is a rare event, and in our experience the establishment of a deglutologic rehabilitative program is effective in most of cases. Permanent major dysphagia was not observed in our experience, in contrast with observations on patients treated with resective techniques [7].
- A posterior pharyngeal ridge has been observed, sometimes associated to a postoperative discomfort of the patient. This mucosal tension generated at the level of the posterior pharyngeal wall apparently has no functional significance and is generally avoidable by reducing palatal suture tension [8].
- Velopharyngeal insufficiency. Unlike ablative techniques, this complication is extremely rare in patients undergoing BRP, especially if surgery is performed properly.
- Acute airway obstruction. Although it is very rare, the possibility of a temporary tracheostomy due to upper airways edema has been described.
- Pharyngeal paresthesia, sensation of dryness, dysgeusia, and lingual hypoesthesia can be referred by patients undergoing transoral surgery. In fact, mouth gag determines a compression on the base of the tongue, causing a transitory ischemic phenomenon with consequent impairment of the sensitive function of the lingual nerve(s) and of the lingual branches of the glossopharyngeal nerve(s). These phenomena are frequent and generally transient. Some surgeons suggest that the probability of this occurrence could be reduced by interrupting the mouth

opening intraoperatively (i.e. between the tonsillectomy and the BRP steps), limiting the ischemic time at the level of the oral tongue and tongue base.

- Post-nasal drip (posterior rhinorrhea), usually transient, is more frequent when a concurrent septo(turbino)plasty is performed.
- Nasopharyngeal stenosis can exceptionally occur, in case of abnormal scarring, especially after invasive palate surgeries. However, the occurrence of this complication in BRP series is not reported [9, 10].

In the 200 patients underwent barbed pharyngoplasty (from January 2019 to April 2021) occurred 9 postoperative bleeding (5.1%), only 1 tracheostomy due to difficulties in the patient reintubation after an immediate postoperative bleeding with a following recovery in ICU. Our group investigated the long-term subjective outcomes of BRP by the means of the PPOPS questionnaire in 2020. In our series only one patient reported moderate residual long-term dysphagia, while no patients complained about severe swallowing impairment. Temporary rhinolalia was reported by 8% of the patients and residual nasal regurgitation by 2% of the patients. None of the patients had residual throat pain at the time of the evaluation. Finally, the majority of patients would encourage other patients to undergo this procedure according to their positive experience [11].

18.2 Special Topic: Extrusion and Exposure [6]

barbed reposition pharyngoplasty has been demonstrated to be a very good technique for both anatomical and functional results [12]. However, different authors have reported the possibility of extrusion or exposure (E&E) of the barbed suture used in this technique in a medium- or long-term period [13, 14].

The term “exposure” stands for the situation in which the barbed suture thread becomes visible in the tonsillectomy surgical bed after the breakdown of the superficial line of interrupted sutures connecting the anterior to the posterior tonsils pillars. On other hand, “extrusion” is observed in the soft palate area, when a short segment of barbed suture shows itself on the mucosal surface (Fig. 18.1).

Over the years the type of barbed suture used for BRP has changed. STRATAFIX™ Spiral PDO 3-0 (Angiotech Puerto Rico Inc., Ethicon) was the thread initially used, while the V-Loc™ 180 3-0 (Covidien, Dublin, Ireland) is now starting to be widely employed.

What happens in case of early extrusion or exposure of the suture? Could this compromise the functional results of the surgical technique? Is it related to the type of thread? Could it impact the subjective perception of the operation?

In this regard, the ENT group of Pierantoni-Morgagni Hospital have recently analyzed the rates of extrusions, implications in the functional and anatomical results, and subjective discomfort in a large group of patients (488 cases) surgically treated for OSA with BRP as a stand-alone procedure (377 cases) or associated with TORS (11 cases), as summarized in Table 18.1 [6].

Fig. 18.1 Black arrow: extrusion of the right soft palate. Red arrow: exposure of the left tonsillar bed

Table 18.1 Rates of extrusion & exposition (E&E)

Total E&E	90/488 (18.4%)	*p*
STRATAFIX™ Spiral PDO™ Plus	25/230 (10.9%)	$p = 0.002$ $\chi 2$: 9.14
V-Loc™ 180	65/258 (25.2%)	
E&E and type of procedure		
Single level BRP	71/377 (18.8%)	$p = 0.68$ $\chi 2$: 0.07
Multilevel BRP-TORS	19/111 (7.1%)	
Early E&E (<7 days)	26/90 (28.9%)	
STRATAFIX™ Spiral PDO™ Plus	6/26 (23.1%)	$p = 0.60$ $\chi 2$: 0.27
V-Loc™ 180	20/26 (76.9%)	
Late E&E (7 days to 2 months)	69/90 (76.7%)	
STRATAFIX™ Spiral PDO™ Plus	20/69 (29%)	$p = 0.50$ $\chi 2$: 0.45
V-Loc™ 180	49/69 (71%)	
Ultra-Late E&E (>2 months)	5/90 (5,5%)	
STRATAFIX™ Spiral PDO™ Plus	1/5 (20%)	$p = 0.72$ $\chi 2$: 0.13
V-Loc™ 180	4/5 (80%)	
Symptomatic clinical profile	56/90 (62.2%)	
STRATAFIX™ Spiral PDS™ Plus)	13/56 (23.2%)	$p = 0.22$ $\chi 2$: 1.54
V-Loc™ 180)	43/56 (76.8%)	
Asymptomatic clinical profile	34/90 (37.8%)	
STRATAFIX™ Spiral PDS™ Plus)	12/34 (35.3%)	$p = 0.21$ $\chi 2$: 1.53
V-Loc™ 180)	22/34 (64,7%)	

In patients who underwent BRP as a stand-alone procedure, a thread extrusion in 18.8% of cases was observed, representing the second most common complication after a transient dysphagia. In patients treated with BRP combined with transoral robotic surgery (TORS) the extrusion was reported in 7.1% of cases. NO statistical differences emerged between these groups ($p = 0.6$). This result, although not statistically significant, could be related to the fact that patients undergoing robotic surgery resumed normal oral feeding more slowly and therefore the palatal region was less stressed in the first days [15]. This hypothesis was confirmed by the timing of E&E. Most of patients manifested these complications after hospital discharge, within 2 months from the procedure, when they resumed a normal diet.

A statistically significant difference between the E&E in those operated with Stratafix and those operated with V-Loc was noted. Patients treated with V-Loc extruded more frequently. This is explainable with different compositions and technologies of the wires. Stratafix™ Spiral PDS Device consists of Polydiaxone, and it is a synthetic absorbable suture where barbs can also be found circumferentially around its surface. The V-Loc™ 180 is synthesized from a copolymer of glycolic acid and trimethylene carbonate, and it presents itself as an absorbable thread with circumferential barbs on its surface. Many studies tested the strength of the two wires for tendon reconstruction in porcine ex vivo model. V-Loc™ demonstrated a higher maximum load. The reason for that distinct biomechanical behavior might be the different shape of the barbs of Stratafix™ and V-Loc™. This ultimately could be the reason why the greater strength generated by the V-Loc™ can result in a higher rate of extrusion in the oral cavity, where the mucosa and muscles cannot resist the excessive tension generated [16, 17].

Analyzing the site of E&E, about half of them were localized in the soft palate, 1/3 in tonsillar bed and the rest in other sites, like pterygomandibular raphe and median raphe. Most of the symptomatic extrusions coincided with the clinical profile of pinpoint pain, mainly localized in soft palate, whilse the tonsillar bed was mostly responsible for an asymptomatic exposure recognized during a scheduled check-up visit.

All the patients were asked to compile the PPOPS questionnaire to evaluate their subjective discomfort after surgery. The mean results of PPOPS in the two groups (extruded vs. non-extruded) have given similar results, with no statistically significant difference. This result is the confirmation that E&E does not affect the patient subjective discomfort of the procedure. Patients who underwent robotic surgery were excluded, due to possible bias in pharyngeal outcomes.

Finally, the impact of E&E on the functional results of the procedure, calculated as difference between the mean delta-AHI in the two groups analyzed (extruded vs. non-extruded), was investigated with a type III polygraphy sleep study. Since no difference has been found in the two groups it appears that E&E does not actually affect the functional outcome of the procedure [18–20].

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Effectiveness of Barbed Repositioning Pharyngoplasty for the Treatment of Obstructive Sleep Apnea (OSA): Prospective Outcomes, Multicentric Studies and Review of Literature Results

19

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In previous chapters, the impact of obstructive sleep apnea (OSA) on patients' morbidity and survival and the evolution of palate surgery with a focus on techniques and complications were discussed [1–28].

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_19

This chapter has been designed to analyze and report the respiratory outcomes of barbed surgery for OSA treatment: the first section is dedicated to a randomized control trial (RCT) supporting barbed repositioning pharyngoplasty (BRP) as an effective therapeutic option for the treatment of OSA; in the second part, a prospective multicenter study regarding BRP is presented. Last but not least the current literature evidence about BRP outcomes for OSA treatment has been summarized.

19.1 Effectiveness of Barbed Repositioning Pharyngoplasty for the Treatment of Obstructive Sleep Apnea (OSA): A Prospective Randomized Trial

19.1.1 Trial Design

This was a single-center randomized controlled trial with two prospective arms. In the first arm patients who met the inclusion criteria underwent BRP. In the second arm patients underwent observation only. Figure 19.1 shows the trial design in detail.

The trial ran for 3 years from February 2015 to February 2018. All patients were adults between 18–65 years who were referred to the Otolaryngology and Head and Neck Department at Hospital Morgagni Pierantoni in Forli, Italy. The inclusion and exclusion criteria are detailed in (Table 19.1).

The run-in period started with a type 3 polygraphy. Patients were consented and recruited in the study in accordance with ethical guidelines. Patients meeting the inclusion criteria after polygraphy were included in the study by randomization. Power calculations determined matched groups in the BRP and observation to have $N = 25$.

For all patients, baseline and 6-month follow-up polygraphy were performed evaluating the apnea hypopnea index (AHI), oxygen desaturation index (ODI), and lowest oxygen saturation (LOS). All sleep studies were carried out unattended by means of a Polymesam Unattended Device 8-channel, reviewed and scored by the same expert in sleep medicine according to the American Academy of Sleep Medicine Guidelines. Body mass index (BMI) was calculated for all participants before and after surgery, with a full medical history, Epworth Sleepiness Scale (ESS) was also collected. Pre-randomization evaluation with drug-induced sleep endoscopy (DISE) was performed for all patients to confirm the palatal/pharyngeal obstruction. DISE was performed with flexible rhinopharyngolaryngoscope in the operating theater using target-controlled infusion (TCI) of propofol to achieve a complete evaluation of the upper airways (UA) collapse with a focus on the lateral pharyngeal walls. Bispectral index (BIS) was used to check the level of sedation during DISE. Scoring during DISE was performed by the authors by consensus in a manner blinded to outcome using the VOTE scale.

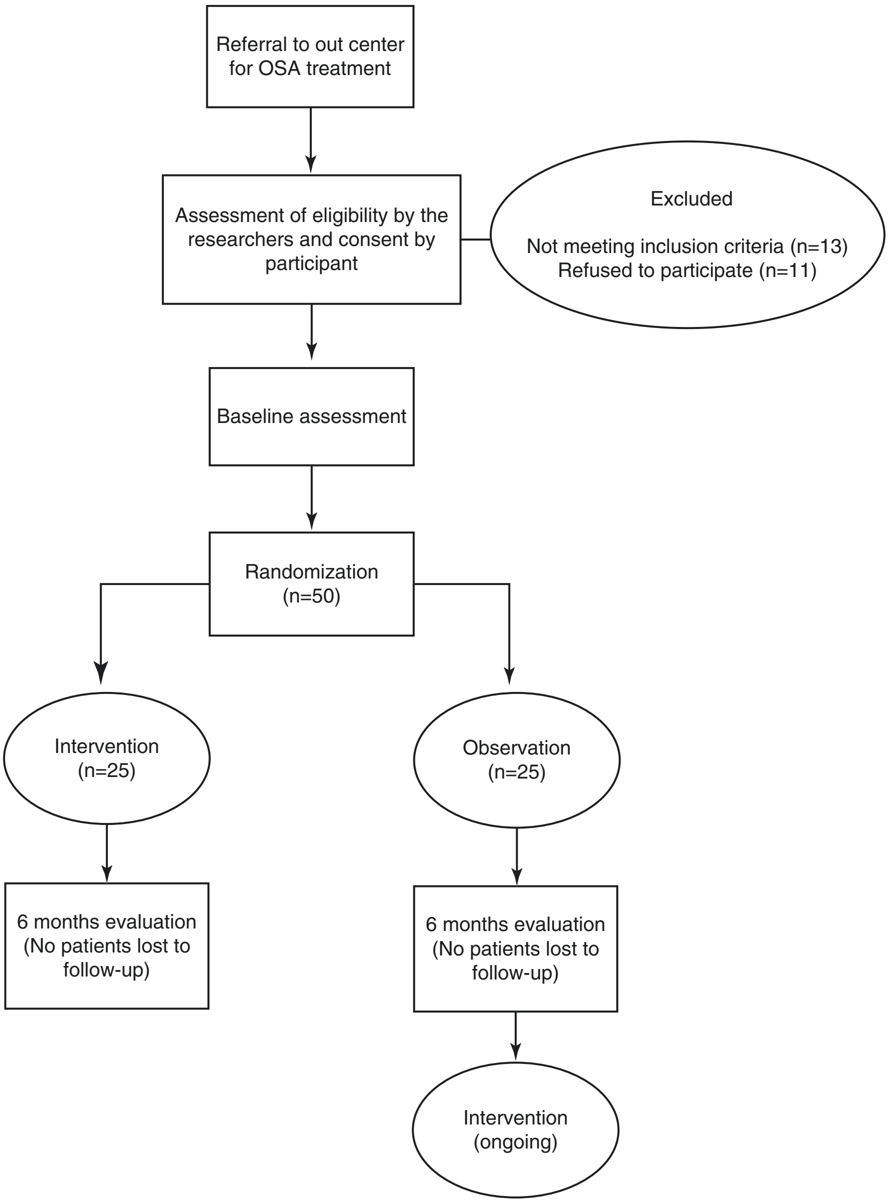

Fig. 19.1 Study design algorithm

Table 19.1 Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
1. Patients suffering from moderate to severe OSA with certain degree of nasal obstruction planned for BRP and tonsillectomy, with nasal surgery (septoturbinoplasty)	1. Serious psychiatric, cardiopulmonary, or neurological disease
2. Grades 1–2 tonsillar hypertrophy	2. American Society of Anesthesiologists (ASA) classification >3
3. Aged between 18 and 65 years old	3. Patients negative to surgery
4. BMI ≤35	4. Previous tonsillectomy and OSA surgery
5. Failure of CPAP or low adherence to this treatment during the last 3 months (<4 g per night)	5. Significant craniofacial anomalies
6. Mainly palatal/pharyngeal collapses at DISE (severe circular palatal collapses and severe transversal pharyngeal collapses with none or mild tongue collapses)	6. Pregnant women
	7. Grades 3–4 tonsillar hypertrophy
	8. Mainly lingual/base of tongue collapses at DISE
	9. Follow-up <6 months

19.1.1.1 Surgical Technique

The surgical technique for BRP has been described in detail in previous chapters.

19.1.2 Results

A total of 50 patients were enrolled in the study, with 25 in the BRP group and 25 in the observation group. One-way ANOVA was used to test differences in age, BMI, and baseline AHI between the two groups, with no significance seen.

A significant postoperative reduction of all outcome measures (AHI, ODI, LOS, and ESS) was recorded in the BRP group, while no significant changes were seen in the observation group (Table 19.2). Table 19.3 shows the comparison of changes of all indices between the two groups. BRP was shown to be more effective than observation. No significant difference in BMI and LOS change was recorded between the two groups.

Logistic regression was used to test the influence of age, baseline BMI, AHI, LOS, and ESS score on the reduction of AHI at 6-month follow-up (delta-AHI). Baseline AHI was related significantly to postoperative AHI in the BRP group. In the observation group, no factors were significantly associated with a reduction in AHI (Table 19.4).

Linear regression modeling showed that high values of baseline AHI predicted more significant postoperative reductions in AHI in the BRP group.

Table 19.2 Paired t-test comparing baseline (pre) with 6-month follow-up data (post) in both groups

Group	*N*	preAHI	postAHI	*P*	preODI	postODI	*P*	preLOS	postLOS	*P*	preESS	postESS	*P*	preBMI	postBMI	*P*
BRP	25	25.58 ± 14.60	9.82 ± 9.88	0.00	24.38 ± 17.72	9.30 ± 10.24	0.00	80.56 ± 7.50	85.84 ± 7.93	0.01	9.28 ± 3.10	3.76 ± 4.42	0.00	26.49 ± 2.51	25.42 ± 2.40	0.13
CONTROL	25	36.83 ± 23.82	31.93 ± 21.89	0.50	35.38 ± 23.31	32.4 ± 22.58	0.68	74.84 ± 10.39	78.61 ± 9.63	0.24	10.4 ± 23.68	10.85 ± 3.91	0.71	27.90 ± 3.53	27.48 ± 3.78	0.71

Table 19.3 Unpaired t-test comparing 6-months follow-up modifications between groups

Group	deltaAHI	P	deltaODI	P	deltaLOS	P	deltaESS	P	deltaBMI	P
BRP	−15.75 ± 14.47	0.01	−15.08 ± 17.93	0.01	5.28 ± 9.16	0.69	−5.52 ± 4.12	0.00	−10.6 ± 1.67	0.08
CONTROL	−5 ± 13.75		−2.84 ± 14.55		4.15 ± 9.24		0.42 ± 1.88		−0.24 ± 1.35	

Table 19.4 Logistic regression to test the influence of age, baseline (pre) BMI, AHI, LOS, and ESS score on the 6-months follow-up (post) reduction of AHI (delta-AHI = post-AHI−pre-AHI)

BRP group	Coefficient	*p*	95% confidence interval	
PreAHI	0.6	<0.01	0.18	1.07
PreBMI	1.71	0.07	−0.15	3.6
PreESS	0.4	0.53	−0.58	0.91
Pre LOS	0.16	0.65	−0.58	0.91
Age	−0.21	0.21	−0.56	0.13
Control group				
PreAHI	0.27	0.3	−0.28	0.82
PreBMI	−0.69	0.65	−3.89	2.5
PreESS	0.17	0.9	−2.73	3.07
Pre LOS	−0.01	0.98	−1.1	1.1
Age	0.14	0.8	−1	1.29

19.1.3 Discussion

Although palatal surgery has been reported to be a successful alternative to CPAP therapy in the treatment of OSA, there is a lack of strong evidence in the literature. Recently, the SAMS trial, which looked at multilevel surgery in patients who failed medical management, demonstrated significant improvement in AHI compared to control in the 102 patients enrolled [15].

In this randomized controlled trial, the authors demonstrated the effectiveness of BRP over a control group, with significant reductions in AHI. ODI and ESS scores also reduced significantly in the BRP group, which had a success rate of 74.2%, with no major complications (e.g. bleeding, significant dysphagia) recorded. Severity of OSA should not be considered a contraindication to BRP, as demonstrated by linear regression that showed higher baseline AHI predicted more significant reduction in AHI postoperatively.

Similar results were demonstrated in the SKUP3 trial, where UPPP was compared to expectant management [13]. However, the higher significance in improvement in this trial suggests that lateral pharyngoplasties, especially BRP, should be performed over UPPP in the treatment of specific OSA patterns observed by means of DISE (e.g. lateral pharyngeal wall collapse). This is supported by some recent retrospective comparative studies evaluating palatal techniques as stand-alone procedures or as part of a multilevel setting [16, 17]. Moreover, a systematic review and meta-analysis in 2016 by Pang et al. demonstrated that other techniques such as expansion sphincter pharyngoplasty (ESP) are superior to UPPP [10]. A meta-analysis by Neruntarat et al. which compared BRP to ESP concluded that the outcomes in both procedures are comparable in the improvement of OSA with palatal collapse. The study showed that BRP had a shorter surgical time over ESP overall [18].

Overall, the results of this RCT, which was the first looking into BRP in the management of OSA, demonstrated that it is a safe and effective surgical method. Further studies are warranted in future in the trial setting, with larger cohorts to demonstrate statistical significance.

19.2 Prospective Multicenter Study on Barbed Reposition Pharyngoplasty Standing Alone or as Part of Multilevel Surgery for Sleep

19.2.1 Material and Methods

This prospective multicenter study investigated the efficacy and safety of BRP in 111 patients affected by OSA, treated between January and September 2016, in 15 ENT institutes—Head and Neck Surgery of different countries.

The inclusion criteria were: patients diagnosed with OSAS with AHI ≥ 5 and major obstruction at the retropalatal level; patients not compliant with CPAP use; failures of previous surgery; age between 21 and 75 years; and body mass index (BMI) ≤ 35; ASA 2.

The exclusion criteria were: patients ≥75 years and/or with severe medical illness; patients with significant craniofacial anomalies affecting the airways; BMI ≥35; patients with limited mouth opening (interincisal distance ≤2 cm); ASA ≥ 2; and patients with less than 6 months of follow-up including postoperative polysomnography (PSG) and Epworth Sleepiness Scale (ESS) data.

1. Preoperative data consisted of:
    - Age and gender
    - Medical history and diseases
    - ENT examination and Müller's maneuverto identify collapsible sites
    - Preoperative ESS evaluation;
    - Preoperative AHI and ODI
2. Intraoperative assessment including intraoperative time and complications
3. Postoperative evaluation:
    - hospitalization and complications, including assessment of swallowing function with the MD Anderson Dysphagia Inventory (MDADI) questionnaire that each patient filled out preoperatively, 1 week and 1 month after surgery.
    - Follow-up at 6 months after PSG, ESS, and BMI surgery

The primary outcomes were defined as a significant postoperative reduction of the preoperative AHI and ESS. In order to have a more detailed and clinically

Table 19.5 Definition of success and failure criteria

Criteria	Definition
Cured	AHI < 5 and ESS < 10 and reduction >50%
No more CPAP needed	AHI < 15 and ESS < 10 and reduction >50%
Success	AHI < 20 and ESS < 10 and reduction >50%
Failure	AHI > 20 and any ESS value and reduction <50%

relevant distribution of outcomes, we stratified our postoperative results into four different levels (Table 19.5).

19.2.1.1 Surgical Technique

The description of surgical technique is available in previous chapters.

In most cases, BRP was a stand-alone procedure that included tonsillectomy and a nasal procedure if needed. In patients who had already undergone tonsillectomy, a superficial removal of the mucosa overlying the muscle was performed. In a few cases, tongue base surgery or thyroidopexy was performed as part of a multilevel sleep apnea surgery. Resorbable polydioxanone (PDO), bidirectional, size 0 (tensile strength size 2-0), length 24× cm, non-cutting (conical tip), needle 36 mm or 26 mm (Quill Sutures, Research Triangle Park, NC) was used.

19.2.2 Statistical Analysis

Associations between variables and endpoints were tested with the Fisher exact or t-tests, as appropriate. A 2-tailed P value less than 0.05 was regarded as statistically significant. T Statistical analysis was performed with STATA 12.0 software (Stata Corp., College Station, TX).

19.2.3 Results

The mean preoperative and postoperative AHI were 33.4 ± 19.5 and 13.5 ± 10.3, respectively ($p < 0.001$). The mean preoperative and postoperative ESS score were 10.2 ± 4.5 and 6.1 ± 3.6, respectively ($p < 0.001$). The mean pre- and postoperative ODI were 29.6 ± 20.7 and 12.7 ± 10.8, respectively ($p < 0.001$).

According to the defined criteria, a success rate of 73% was recorded (Table 19.6).

The mean preoperative and postoperative BMI were 27.9 ± 3.2 and 27.3 ± 3.0 respectively. The mean operative time of palatal procedure was 25 ± 4.2 min, with lower figures recorded in centers with high volume activity.

All patients were allowed to restore the oral feeding within the second day after surgery.

Intraoperative and postoperative complications are summarized in Table 19.7. No intraoperative complications were recorded in 103 patients (93% of the cases)

Table 19.6 Outcomes

Criteria	No. of patients	Proportion (%)	Cumulative (%)
Cured	23	20.7	20.7
No more CPAP needed	46	41.4	62.2
Success	12	10.8	73.0
Failure	30	27.0	27.0

Table 19.7 Complications

No. of cases		%
Intraoperative complications		
No complications	103	93
Partial thread extrusion	3	3
Intraoperative bleeding	3	3
Needle broken	1	1
Suture rupture	1	1
Postoperative complications		
No complications	75	68
Partial thread extrusion	7	6
Postoperative bleeding	6	5
Dysphagia	23	21

while a partial thread extrusion was observed in 3 cases. Moreover intraoperative self-limited bleeding was seen in 3 patients and the rupture of needle or thread was observed in 2 cases. No postoperative complications were recorded in 75 patients (68% of the cases).

The most common complaint was transient dysphagia (21%), recovered within 6 days in all patients. The preoperative mean MDADI score was 3.67 ± 2.58, while the postoperative first week and 1-month scores were 11.18 ± 4.32 and 5.06 ± 1.83, respectively.

Partial thread extrusion was the second most common complication (6% of the procedures). Postoperative bleeding was seen in 6 patients (5% of the procedures). In 4 of these 6 patients, late postoperative bleeding was self-limited and did not require operative intervention. Only 1.8% of the patients required an additional surgical procedure to control the bleeding.

19.3 Current Literature Evidence

The flow diagram shown in Fig. 19.2 (PRISMA flow diagram) describes the selection process that includes 15 studies for a total of 1531 patients, out of which 1061 underwent barbed reposition pharyngoplasty. The current literature evidence about BRP outcomes for OSA treatment and the baseline characteristics of the studies has been summarized in Table 19.8.

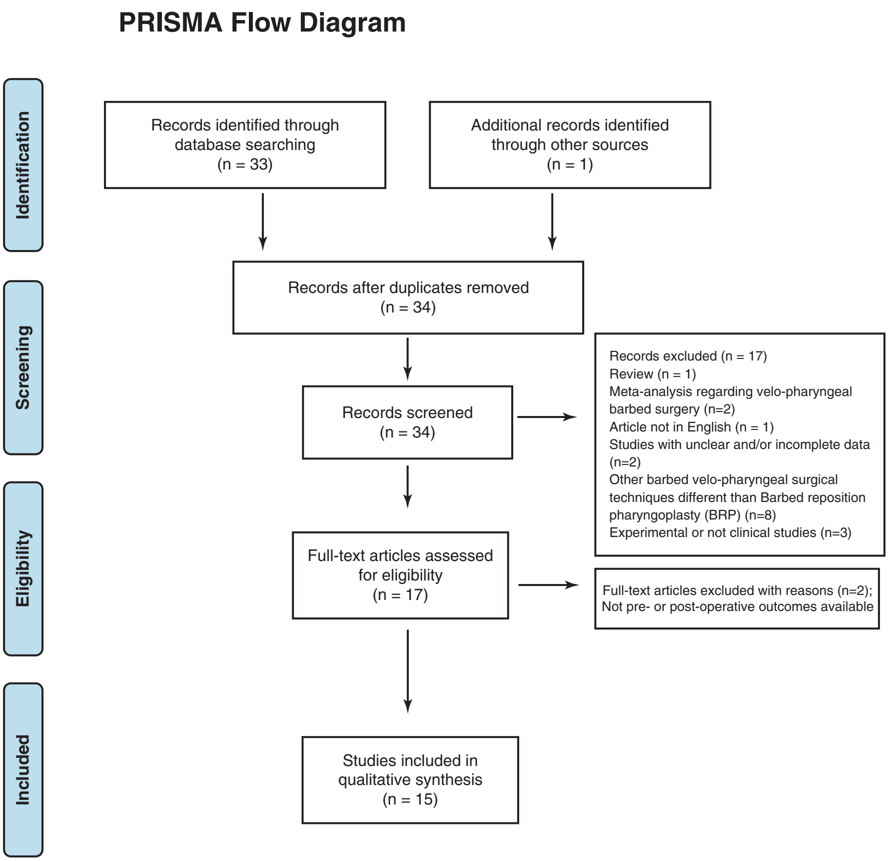

Fig. 19.2 Selection process that includes 15 studies for a total of 1531 patients, out of which 1061 underwent barbed reposition pharyngoplasty

Five trials were uncontrolled prospective studies (215 patients, 14% of total) [12, 20, 29–31], nine were retrospective studies (1266 patients, 82.6% of total) [16, 17, 21, 28, 34–36], and one randomized prospective clinical trial (RCT) (50 patients, 3.32% of total) [32].

All analyzed studies reported good outcomes after BRP surgery. Average preoperative values of AHI and ODI reduced in all studies considered with a significative statistical difference between preoperative and postoperative values ($p < 0.05$ in all cases—see Table 19.8). The surgical success rate (defined as a postoperative reduction in the AHI of 50% and/or a postoperative AHI of 20/h) was reported in 11 studies. The postoperative surgical success rate ranged between 65.4 and 93% of cases.

According to literature results BRP could be considered to be an easy-to-learn, quick, safe, and effective new palatopharyngeal procedure, which can be used in a single-level surgery or as a part of multilevel procedures. Patients affected by severe OSA may benefit from this surgery with more significant reduction of AHI values.

Table 19.8 Current literature evidence about BRP outcomes for OSA treatment

Author year	Study design (uni o multicenter)	Inclusion criteria	Surgical technique	Mono/ multilevel surgery	Number of cases	Mean age	Sex (M:F)	AHI-pre	AHI-post	ODI-pre	ODI-post	BMI	Surgical success rate[a]	Follow-up (months)	Surgery complications
1. Vicini et al. 2015 [12]	Retrospective	OSAHS patients DISE pattern of velo-paryngeal collapse	BRP	Single level surgery	10	53 ± 12.4	1:0	43.65 ± 26.8	13.5 ± 15.41	44.7 ± 27.32	12.9 ± 16.3	28.5 ± 3.6	90%	6	No significative complications
2. Vicini et al. 2017 [29]	Prospective	OSAHS patients DISE indicating an obstruction at base of tongue and at soft palate	BRP + TORS	Multilevel surgery	10	64 (45–74)	–	32.7	16.9	–	–	27.9	70%	12	No complications
3. Cammaroto et al. 2017 [17]	Retrospective	OSAHS patients DISE indicating collapse to retropalatal, retrolingual and hypopharyngeal levels	BRP + TORS	Multilevel surgery	10 BRP 10 ESP 10 UPP	BRP 48.2 ESP 52.8 UPPP 58.4	9:1	BRP 34.04 ESP 35.59 UPPP 37.84	BRP 13.53 ESP 9.63 UPPP 22.9	–	–	BRP 28.77 ESP 27.03 UPPP 26.79	BRP 90% ESP 90% UPPP 50%	6	No complications
4. Montevecchi et al. 2017 [30]	Prospective	OSAHS patients with single level palatal collapse	BRP	Single level surgery BRP 94.6% Multilevel (BRP + septoturbino-plasty 5.4%)	111	46.3 ± 10.5	8.3:1.7	33.4 ± 19.5	13.5 ± 10.3	29.6 ± 20.7	12.7 ± 10.8	27.9 ± 3.2	73%	6	93% no intraoperative complications (103 pts); 3 partial extrusion, 3 intraoperative self-limited bleeding; 1 suture rupture; 1 needle rupture 68% No postoperative complications (75 pts); 21% dysphagia recovered in 6 days, 6% partial thread extrusion; 5% self-limited bleeding postop; 1.8% additional surgery procedure

(continued)

Table 19.8 (continued)

Author year	Study design (uni o multicenter)	Inclusion criteria	Surgical technique	Mono/ multilevel surgery	Number of cases	Mean age	Sex (M:F)	AHI-pre	AHI-post	ODI-pre	ODI-post	BMI	Surgical success rate[a]	Follow-up (months)	Surgery complications
5. Rashwan et al. 2017 [16]	Retrospective	OSAHS patients with BMI<=35 and velo-pharyngeal collapse	BRP vs. ESP vs. UPPP	Multilevel surgery	25 BRP 25 ESP 25 UPPP	–	–	BRP 25.58 ± 14.68 ESP 19.14 ± 9.66 UPPP 18.96 ± 17.79	BRP 15.76 ± 14.5 ESP 10.13 ± 5.3 UPPP 6.08 ± 5.5	BRP 24.39 ± 17.23 ESP 16.30 ± 8.95 UPPP 17.56 ± 16.64	BRP 15.09 ± 17.6 ESP 6.48 ± 7.9 UPPP 7.13 ± 6.8	–	BRP and ESP are effective; UPPP 16–83% depending on criteria, 40% in unselected patients	6	None particularly in BRP. Generally: difficulty swallowing, nasal regurgitation, taste disturbance, voice changes + velopharyngeal stenosis
6. Madkikar et al. 2019 [20]	Prospective	OSAHS patients DISE indicating a purely nasal and retropalatal obstruction, BMI ≤ 38, refusing C-PAP	BRP	Multilevel surgery	50	–	–	40.6	10.2	Mean preop, 42.7/h	Mean postop, 12.6/h	–	–	12	Minor complications: slipping of the palatopharyngeal muscle due to tear through, leading to the barb suture loop showing (2)
7. Babademez et al. 2019 [31]	Prospective	OSAHS patients DISE indicating retropalatal obstruction, absence of nasal obstruction due to turbinate hypertrophy or septal problem, and tonsillar hypertrophy more than grade 2 BMII ≤ 35	MBRP vs. BRP	–	17 BRP 17 MBRP	BRP 39.4 ± 7.5 (26–58) MBRP 40.6 ± 2.4 (27–58)	BRP 14:3 MBRP 15:2	BRP: preop, 29.9 ± 17.6; MBRP: preop, 32.5 ± 17.8; Supine: BRP: preop, 40 ± 7.4; MBRP: preop, 49.3 ± 26.5	BRP: postop, 5.4 ± 2.5; MBRP: postop, 7.7 ± 6.6 Supine: BRP: postop, 13.2 ± 5.5; MBRP: postop, 14 ± 8.9	Snoring VAS score: BRP: preop, 6.2 ± 1.9; postop, 2.2 ± 1; MBRP: preop, 8 ± 1.5, postop, 1.8 ± 0.8	–	BRP = 27.9 ± 3 MBRP = 27 ± 2.5	BRP: 82% MBRP: 95%	6–9 (mean 8)	Most of the patients in both groups reported only a mild pain in swallowing that resolved in a few days; many reported a foreign body sensation on the soft palate that resolved spontaneously in a month

8. Vicini et al. 2020 [32]	Single-center prospective controlled trial with two parallel arms and randomisation	1. OSAHS patiens with AHI ≥ 15 events/h) with certain degree of nasal obstruction planned for BRP and tonsillectomy, with nasal surgery (septoturbino-plasty) 2. Grades 1–2 tonsillar hypertrophy 3. Aged between 18 and 65 years old 4. BMI ≤ 35 5. Failure of CPAP or low adherence to this treatment during the last 3 months (<4 h/night) 6. Mainly palatal/pharyngeal collapses at DISE (severe circular palatal collapses and severe transversal pharyngeal collapses with none or mild tongue collapses)	BRP vs. observa-tion group	Mono level surgery	25 BRP 25 control group	BRP 44.64 Control group 50.09	–	BRP 25.58 + −14.6 Control group 36.83 ± 23.82	BRP 9.82 ± 9.88 Control group 31.93 ± 21.89	BRP 24.38 ± 17.72 Control group 35.38 ± 23.31	BRP 9.30 ± 10.24 Control group 32.4 ± 22.58	BRP PRE 26.49 ± 2.51 POST 25.42 ± 2.40 Control PRE27.90 ± 3.53 POST 27.48 ± 3.78	74.2% BRP	6	No complications

(continued)

Table 19.8 (continued)

Author year	Study design (uni o multicenter)	Inclusion criteria	Surgical technique	Mono/ multilevel surgery	Number of cases	Mean age	Sex (M:F)	AHI-pre	AHI-post	ODI-pre	ODI-post	BMI	Surgical success rate[a]	Follow-up (months)	Surgery complications
9. Iannella et al. 2020 [33]	Retrospective	OSAHS Patients treated with BRP	BRP	Single level surgery	140	49	13:1	31.5	11.4	–	–	BMI <25 (26%), 25–30 (51%), >30 (23%)	91% of cases, the problem cleared up spontaneously	Average 26 From 2–56	Complications 51% of patients complained of swallowing problems after surgery. In 91% of cases, the problem cleared up spontaneously. At the time of the interview, only 9% of patients had a residual swallowing difficult. At the time of PPOPS evaluation, rhinolalia was observed in 8% of patients, whereas nose regurgitation was present in 2% of patients. In 20% of patients, the foreign body sensation was present during follow-up
10. Minni et al. 2019 [28]	Retrospective	OSAHS patients Aged between 25 and 75 years, BMI >15 and <35, any degree of tonsillar volume, apnea-hypopnea index (AHI) >15, and failure of preoperative CPAP treatment	BRP vs. UPPP vs. BRP+HS Vs. UPPP+HS	Multilevel surgery	80 UPPP + 42 BRP UPPP 38 UPPP+ HS 42 BRP 20 BRP+HS 22	UPPP 43 (37–47) BRP 42 (38–47)	UPPP 1.76:1 (51 males 63.8%) BRP 0.9:1 (20 males 47.6%)	UPPP 27 (24–29) UPPP +HS 27 (24–29) BRP 29 (28–31) BRP +HS 28 (26–30)	UPPP 16 (14–17) UPPP +HS 11 (10–11) BRP 10 (9–11) BRP +HS 10 (9–11)	UPPP 24 (23–25) UPPP+HS 17 (16–18) BRP 17 (16–18) BRP+HS 20 (20–23)	UPPP 18 (17–19) UPPP+HS 13 (12–14) BRP 12 (11–12) BRP+HS13 (11–13)	UPPP preop 25 (24–26) Post op 23 (21–24) BRP preop 27 (25–28) Post op 24 (23–25)	–	18	The execution of HS reduces the latero-lateral hypopharyngeal collapse with the result of increasing the transverse diameters of the upper pharynx, optimizing in this way the action of the UPPP procedure. Contrarily, BRP guarantees an effective retropalatal enlargement without the necessity of HS

11. Gulotta et al. 2021 [34]	Retrospective	OSAHS patients Analyze E&E, its implications in the functional, anatomical results and subjective discomfort in OSA patients treated with BRP	BRP or Multilevel TORS	Multilevel	488 BRP 230 Stratafix, 258 V-Loc wire	51.97 ± 11.38	12.5:1	40.02 ± 19.35	23.8 ± 21.35	–	–	–	–	–	E&E are suture-type sensitive (V-Loc > Stratafix), reported more frequent when BRP is performed alone than BRP-TORS with no statistical significance. 76.7% of the E&E occur after patient discharge and within 2 months. About half of the E&E were localized in soft palate
12. Babademez et al. 2019 [35]	Retrospective	OSAHS patients with mild or moderate OSA without previous surgery	BRP vs. ESPwAP	Single level surgery	45 BRP 53 ESPwAP	BRP 37.3 ±8.9 ESPwAP 41.6 ± 9.4	BRP 31:14 ESP-wAP 41:12	BRP 25.9 ESPwAP 28.5	BRP 7.4 ESPwAP 9.1	–	–	BRP 29.3 ± 3.1 ESPwAP 28.8 ± 4.2	BRP 86.6% ESPwAP 84.9%	BRP 7.2 ± 4.5 ESPwAP 7.1 ± 6.1	Postoperative pain in BP was less than ESPwAP. Both types of surgeries are effective with comparable results. The BP technique may be preferred when possible to avoid soft tissue excision and seems to be a less invasive procedure
13. Pang et al. 2020 [21]	Retrospective case-series analysis, multicenter	OSAHS patients treated with nose and palate surgery of the upper airway between 2009 and 2016: adult patients (>18 years old), AHI > 5	40 BRP, 50 ESP, 34 FEP, 64 mUPPP, 11 UPF 9 SP, 8 RP, 1 ZPP	Multilevel surgery	217: 40 BRP	43.9: 12.5	187: 30	30.5	19.1	–	–	25.9 ± 4.7	–	41.3	40 BRP: dry throat 2, throat lump 1 throat phlegm 4 throat scar 0 dysphagia 0 symptom complaint 7

(continued)

Table 19.8 (continued)

Author year	Study design (uni o multicenter)	Inclusion criteria	Surgical technique	Mono/ multilevel surgery	Number of cases	Mean age	Sex (M:F)	AHI-pre	AHI-post	ODI-pre	ODI-post	BMI	Surgical success rate[a]	Follow-up (months)	Surgery complications
14. Missale et al. 2020 [33]	observational retrospective	OSAHS who refused or failed to tolerate CPAP and who underwent non-resective pharyngoplasty between January 2014 and October 2017	70 patients 28 ESP 22 BRP 20 BSP	Single 40% to multilevel 60%	28 ESP 22 BRP 20 BSP	53 ± 12	60:10	28 (22.3–35.8)	6 (5–8)	22.5 (20–30)	4 (2–6)	–	93%	6	None
15. Carrasco et al. [36]	Retrospective	Retrospective study of surgically treated OSAS patients who did not tolerate conventional positive airway pressure (CPAP) and who underwent BRP surgery	BRP	Single level surgery	26	42.5 ± 11.5	9:1			–	–	29.1 ± 4.3	65.4%	6	1. Post-tonsillectomy bleeding in two patients 2. Nasopharyngeal insufficiency during the first week in two patients 3. Partial extrusion of the suture in 13 cases

14 studies selected, including 1505 patients with OSAHS total, of which 1035 underwent BRP

AHI apnoea-hypopnea index, *BMI* body mass index, *BRP* barbed reposition pharyngoplasty, *SP* barbed suspension pharyngoplasty, *DISE* drug-induced sleep endoscopy, *E&E* extrusion & exposition, *ESP* expansion sphincter pharyngoplasty, *ESPwAP* expansion sphincter pharyngoplasty with anterior palatoplasty, *FEP* functional expansion pharyngoplasty, *HS* hyoid suspension, *MBRP* modified barbed reposition pharyngoplasty, *mUPPP* modified UvuloPalatoPharyngoPlasty, *ODI* oxygen desaturation index, *OSAHS* obstructive sleep apnoea hypopnea syndrome, *PPOPS* palate postoperative problem score, *RP* relocation pharyngoplasties, *SP* suspension pharyngoplasty, *TORS* transoral robotic surgery, *UPF* UvuloPalatal flap procedure, *UPPP* UvuloPalatoPharyngoPlasty, *ZPP* Z-PharyngoPlasty

[a]Surgical success rate defined as a postoperative reduction in the AHI of C50% and/or a postoperative AHI of 20/h

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20 Palate Postoperative Problems Score (PPOPS): Tool for the Evaluation of Subjectives Results of Palatal Surgery Techniques

Mohamed S. Rashwan, Domenico Michele Modica, Salvatore Gallina, and Francesco Lorusso

20.1 Introduction

OSAHS (obstructive sleep apnea-hypopnea syndrome) is a disease characterized by upper airway obstruction resulting in the absence or reduction of oro-nasal airflow [1] in the presence of thoracoabdominal movement.

The prevalence of the disease is around 3–7%, and there are many factors that predispose to this condition such as age, male gender, obesity, family history, menopause, craniofacial abnormalities, and voluptuous habits such as cigarette smoking and alcohol abuse [2].

Today, palatal surgery is a reference point in OSAHS treatment, and the most commonly used surgical techniques are: uvulopalatopharyngoplasty (UPPP) [3, 4], expansion sphincter pharyngoplasty (ESP) [5, 6], barbed reposition pharyngoplasty (BRP) [7], and anterior pharyngoplasty (AP) [8, 9]. UPPP is based on dissection of the soft palate and removal of the uvula.

ESP is performed after tonsillectomy [10] and is based on “palatal pharyngeal muscle dissection” and its repositioning.

BRP requires barbed sutures located within the soft palate to widen the lateral pharyngeal wall. AP relies on a rectangular incision between the soft palate and hard palate to widen the anterior-posterior space of the pharyngeal wall.

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_20

These three different techniques are very different for the surgeon, but more importantly for the patient.

The aim of our work is to compare the results of the palatal surgical techniques used in our practice in OSAHS patients; in particular we evaluated each surgical technique in the postoperative course and examined the degree of patient satisfaction, so we used a current score recommended by Rashwan et al. called PPOPS (Palate Postoperative Problems Score) [11] (Table 20.1).

Table 20.1 PPOPS questionnaire [11]

PALATE POST-OPERATIVE PROBLEMS SCORE (PPOPS)

Name ____________________ Age _____ Phone __________

Date and type of operation ____________________

Date of questionnaire and examination____________________

☐ Never / spontaneously / no = 0
☐ days / with your doctor / mild / rarely = 1
☐ weeks / with the speech therapist / moderate / often = 2
☐ months / unresolved / severe / = 3

1) Did you have any swallowing problems after surgery ☐never ☐days ☐weeks ☐months?

2) The problem resolved ☐spontaneously ☐ with your doctor ☐ with the speech therapist ☐unresolved.

3) Residual difficulty in swallowing ☐no ☐mild ☐moderate ☐severe?

4) Residual nasal tone of voice ☐no ☐mild ☐moderate ☐severe?

5) Residual regurgitation of liquids into the nose ☐never ☐rarely ☐often ☐always?

6) Any weight loss recorded after surgery ☐no ☐mild ☐moderate ☐severe?

7) Any foreign body sensation in the throat ☐no ☐mild ☐moderate ☐severe?

8) Do you feel sticky mucus in the throat ☐no ☐mild ☐moderate ☐severe?

9) Painful sensation in the throat at rest ☐no ☐mild ☐moderate ☐severe?

10) Painful sensation in the throat while swallowing ☐no ☐mild ☐moderate ☐severe?

11) Do you have a different and worse feeling in the throat after surgery ☐no ☐mild ☐moderate ☐severe?

12) Do you discourage the procedure to others ☐no ☐mild ☐moderate ☐severe?

ITEM for each score from 0 to 3
TOTAL SCORE: 0 to 36

TOTAL SCORE ____________

20.2 Definitions

The idea of the PPOPS score was to formulate a questionnaire in such a way that we can evaluate in a practical way the postoperative patient satisfaction and complications of different types of palate procedures, besides addressing in a more practical and realistic way the most important and common complaints and complications that can occur after any type of palate surgery with the aim to improve the quality of life (QOL).

Help the sleep surgeon to evaluate the advantages and disadvantages of each technique used in palate surgery in the patient's own words, which is very important in the era of palate surgery to optimize the surgery and reduce the side effects.

The questions were based on regular complaints and remarks noted by patients in the postoperative period of various palatal procedures. The PPOPS questionnaire consisted of 12 questions and the answers were recorded on a scale of 0 to 3 with a total score up to 36.

The questionnaire focuses on the most important and common complaints and complications that may occur after any palatal procedure, as the main goal of the procedure is patient satisfaction. The PPOPS questionnaire is shown in Table 20.1.

20.3 Discussion

Rashwan et al. [11], first presented the PPOPS questionnaire through a pilot study between two groups of patients who underwent palate surgery. Twenty patients were selected per group, in order to compare between two techniques, namely ESP and BRP. In this study, they tried to create a questionnaire that can be used in the postoperative evaluation for palate surgery to assess the patient's perception of their surgery. Keeping in mind that there is recall bias in any retrospective study, the authors tried to minimize the bias as much as possible. A well-trained author was busy interviewing patients while completing the questionnaires, trying to obtain as much accurate information as possible. The questions were based on the regular complaints and remarks noted by the patients in the postoperative period of various palatal procedures. The PPOPS questionnaire consisted of 12 questions and the answers were recorded on a scale of 0 to 3 with a total score of up to 36. PPOPS questionnaire focuses on the most important and common complaints and complications that may occur after any palatal procedure, as the main goal of the procedure is patient satisfaction. The PPOPS questionnaire is shown in Table 20.1.

All patients in the two groups were called to obtain their responses for the questionnaire. The questionnaire was formulated in two versions: An English version and an Italian version to obtain the answers in the native Italian language. Patients were first informed about the idea of the questionnaire. Only patients who had undergone palate surgery with or without tonsillectomy or nasal surgery were included in the study; patients with multilevel surgery including tongue base reduction or epiglottoplasty were excluded.

20.4 Results

The response rate for the PPOPS questionnaire was 100%, with all patients completing all parts of the questionnaire. The average time to complete the questionnaire was 15.2 min in both groups.

PPOPS results were recorded in patients who had surgery in the last 4 years. The average time after surgery for ESP was 39.95, while for BRP patients it was 11.23.

The mean total score was calculated and compared between the two groups. The score of BRP group was 4.05 lower than that of ESP group, which was 4.35, with a P value of 0.4, as shown in Table 20.2.

In this chapter, the results of each item are described separately to better understand the disadvantages of each procedure by patients' perception.

The first question asked about swallowing problems after surgery. The results were lower for BRP 0.85 than for ESP 1.45, *P* value 0.028, as shown in Table 20.2.

The second question was related to the resolution of swallowing problems and showed that they were spontaneously resolved in BRP group with a mean value of 0, while they were solved in ESP group with 0.15 in ESP group with a P value of 0.165, as shown in Table 20.2.

The third item, which asked about remaining swallowing problems, was higher in the BRP group with 0.20 than in the ESP with 0.15 (*P* value: 0.378), as shown in Table 20.2.

The fourth item asked about residual nasal tone perceived by the patients, the responses were lower in ESP 0.30 than in BRP 0.35, *P*-value: 0.402, as shown in Table 20.2.

The fifth item asked about residual regurgitation of liquids into the nose and was higher in ESP group with average score of 0.30 than the BRP group with an average score of 0.20, *P*-value: 0.28, as shown in Table 20.2.

Table 20.2 Outcomes from PPOPS questionnaire [11]

Questions	BRP (means)	ESP (means)	*P*-Value
N.1	0.85	1.45	0.0285*
N.2	0	0.15	0.1649
N.3	0.20	0.15	0.3783
N.4	0.35	0.30	0.4018
N.5	0.20	0.30	0.2836
N.6	0.65	0.80	0.2911
N.7	0.35	0.30	0.4116
N.8	0.80	0.40	0.0674
N.9	0.05	0	0.1649
N.10	0.10	0.10	1.0000
N.11	0.45	0	0.0079*
N.12	0.05	0.40	0.0197*
Total score	4.05	4.35	0.4079

Asterisks represent significance (P value < 0.05)

The sixth item was about weight loss after surgery, which was higher in the ESP group with a mean score of 0.80 than the BRP group with a mean score of 0.65, *P*-value: 0.29, as shown in Table 20.2.

The seventh question was regarding foreign body sensation in the throat, which was higher in the BRP group with a mean score of 0.35 than in the ESP group with 0.30, *P*-value: 0.41, as shown in Table 20.2.

The eighth question was related to the feeling of sticky mucus in the throat, which was higher in BRP patients with a mean score of 0.80 than in ESP patients with 0.40, *P*-value: 0.067, as shown in Table 20.2.

The ninth item asked about painful feeling in the throat at rest, the complaint was higher in BRP patients with a mean score of 0.05. None of the ESP patients were positive for this complaint, *P*-value: 0.165, as shown in Table 20.2.

The tenth question asked whether there was a painful sensation in the throat when swallowing. The mean score was the same in both groups, 0.10, *P*-value: 1.00, as shown in Table 20.2.

The eleventh question was: do you have a different and worse feeling in the throat after surgery? The response was higher in the BRP group with a mean score of 0.45 and zero in the ESP group, *P*-value: 0.008, as shown in Table 20.2.

The last question was whether the patient advised others against the procedure. The response was higher in the ESP patients with a mean score of 0.40 and lower in the BRP patients with 0.05, *P*-value: 0.0197, as shown in Table 20.2 [11].

Modica et al. [12], conducted a retrospective study on a sample of 40 patients who underwent palate surgery for OSAHS, 37 men and 3 women, mean age 49.8 years old, followed up by the Palermo University Otolaryngology Unit from January 2013 to December 2017.

Surgical techniques analyzed were: ESP, UPPP, AP, and BRP. Forty patients were enrolled who were fairly classified into four surgical categories. The mean age was 49.8 years; in each surgical category, the mean age was: ESP: 56.7; UPPP: 46.4; AP: 46.7; BRP: 43.4.

All patients answered all questions, so a homogeneous context was obtained and could compare group results.

The first question examines swallowing problems after surgery. The mean scores were: ESP 1.54, UPPP 1.2, AP 1.14 and BRP 0.6, as shown in Table 20.3. The second question aims to know how these swallowing problems, which were investigated with the previous question, were resolved. The mean scores were: ESP 0.46, UPPP 0, AP 0, and BRP 0.

The third question examined the remaining swallowing problems, as this is one of the most important complaints in the postoperative period. Mean scores were: ESP 0.61, UPPP 0.2, AP 0, and BRP 0.2. Question 4 examined residual nasal voice tone. Mean values were: ESP 0.3, UPPP 0, AP 0, and BRP 0. Question 5 examined whether nasal secretions were present after surgery, we asked for an answer without considering flu season or other causes that could explain these fluids. The mean values were: ESP 0.23, UPPP 0, AP 0, and BRP 0.2. Question 6 examines weight loss after surgery, which refers to the period immediately after surgery and is thus closely related to nutrition during this period. The mean values were: ESP 0.61,

Table 20.3 Outcomes from PPOPS questionnaire [12]

Question	AP (means)	ESP (means)	UPPP (means)	BRP (means)
No. 1	1.14	1.54	1.2	0.6
No. 2	0	0.46	0	0
No. 3	0	0.61	0.2	0.2
No. 4	0	0.3	0	0
No. 5	0	0.23	0	0.2
No. 6	0.71	0.61	0.8	1.2
No. 7	0.07	0.38	0	0
No. 8	0.14	0.54	0.2	0.2
No. 9	0	0.23	0	0
No. 10	0	0.08	0	0
No. 11	0	0.38	0.4	0
No. 12	0.14	0.54	0	0
Total	2.21	5.92	2.8	2.4

Table 20.4 Outcomes of comparing the mean total score of each surgical technique [12]

Techniques comparison	*P* value
ESP-BRP	0.0065[a]
AP-ESP	0.03[a]
UPPP-ESP	0.02[a]
AP-BRP	0.99
UPPP-BRP	0.99
UPPP-AP	0.97

[a]Significance with $P < 0.05$

UPPP 0.8, AP 0.71, and BRP 1.2. Question 7 examines foreign body sensation, which is variable according to surgical technique. The mean scores were: ESP 0.38, UPPP 0, AP 0.07, and BRP 0. Question 8 examines the feeling of sticky mucus in the throat. The mean scores were: ESP 0.54, UPPP 0.2, AP 0.14, and BRP 0.2. Question 9 examines the painful sensation in the throat at rest. The mean scores were: ESP 0.23, UPPP 0, AP 0, and BRP 0. Question 10 examines painful sensation in the throat during swallowing. The mean scores were: ESP 0.08, UPPP 0, AP 0, and BRP 0. Question 11 examines whether there is a different and worse feeling in the throat after surgery and analyzes the differences between before and after surgery. The mean scores were: ESP 0.38, UPPP 0.4, AP 0, and BRP 0. Question 12 examines whether the patient advises others against the surgery. The mean scores were: ESP 0.54, UPPP 0, AP 0.14, and BRP 0 [12].

Overall, the mean scores in the four groups were: AP 2.21, ESP 5.92, UPPP 2.8, and BRP 2.4. Statistically significant differences were found between the four techniques, as shown in Table 20.4. The scores of ESP were statistically higher than those of the other techniques (BRP, AP, and UPPP) (P <0.05). Pairwise comparisons between the other three techniques (AP, UPPP, and BRP) had a ($P > 0.05$), suggesting that the questionnaire scores for these techniques were similar.

One of the issues raised by Rashwan et al. [11] was the possibility that the time between surgery and interview might be affected by recall bias, so they decided to focus their attention on a 5-year period. During Modica et al. study [12], it was found that there were no differences in the outcomes of patients who underwent the surgery in different years.

20.5 Discussion

The PPOPS score is a valid tool for evaluating postoperative patients for each technique, but it is particularly useful for comparing outcomes among surgical groups. Indeed, it could prove to be a useful tool to promote and improve the exchange of information on surgical techniques between different surgeons. In addition, we think that it can also be a useful guide for the patient to choose, together with the surgeon, the type of surgery to be performed.

Rashwan et al. [11] tried to get a clearer review of the postoperative complaints described by the patients, for example, the BRP, if we go through the findings and try to analyze each item separately. Patients had higher ratings for foreign body sensation in the mouth, sticky mucus throat sensation, and pain sensation in the throat at rest, which may be attributed to the barbed suture being introduced.

At the same time, the least number of patients discouraging their performed palatal surgery was for the BRP group (question n. 12), this data was significantly lower in comparison with the other group. Moreover, BRP patients had some kind of troubles immediately after surgery but they recommended the procedure, probably because the postoperative complaints were transient and resolved quickly.

Modica et al. [12], compared two other techniques: AP and UPPP, since they represent two important pillars of palatal surgery. Most patients had swallowing difficulties after surgery, but in most cases they were well resolved. There were better results in the BRP group, whereas the highest score was in the ESP group. These data are predictable by the nature of the surgical procedure: In the BRP technique, the soft palate is elevated with a suture; in the ESP technique, the palatopharyngeal muscle is transected and repositioned. Data analysis showed that the ESP group had the highest incidence of residual dysphagia. In the ESP group, two patients had moderate difficulty and the others had mild dysphagia. No residual swallowing difficulties occurred in the AP group. We must keep in mind that this type of surgery is often supported by other surgical treatments such as tonsillectomy [10] or nasal surgery [1]. This is important to increase surgical outcomes and improve airflow through the upper airway. Only in the ESP group, there was residual nasal tone in few patients. Few patients evenly distributed between ESP and BRP groups reported this residual regurgitation, but it was a small number. ESP group had better results in terms of weight loss. Patients who underwent palate surgery necessarily consumed liquid food, later they were introduced semi-liquid food in their meal and at the end solid food. The caloric restriction imposed by this type of diet and the difficulty in swallowing are responsible for the weight loss. We considered mild weight loss (0–5 kg), moderate (6–10 kg), and severe (10 kg). All patients returned to their pre-surgery weight after reintroduction of a normal diet; the patients with the higher weight loss were in the BRP group.

There was no foreign body sensation, pain sensation, or swallowing in the BRP group. The data showed that few patients experienced foreign body sensation, and when they did, the sensation was mild or moderate, never severe.

In the ESP group, the sticky mucus sensation was worse than in all other groups. Painful sensation at rest was shown only by the ESP group, this is important because these patients had daily pain and therefore had a negative perception of the surgical results.

The UPPP group had the worst score for sore throat during swallowing, which is probably due to the fact that this surgical procedure, including dissection of the soft palate, causes pain by contraction of the neck muscles or by the bolus touching the palate and pharyngeal mucosa. However, none of the techniques studied resulted in a worse feeling in the pharynx after the procedure.

The most discouraged procedure by the patients was the ESP, while, UPPP, AP, and BRP had the same results. This is the most difficult question because it seeks to understand whether patients have a good postoperative course and whether the surgery has improved the OSAHS. Some patients said they chose to have surgery rather than use CPAP every night. We must keep in mind that surgery sometimes does not solve OSAHS, but can be good to reduce CPAP pressure [1]. Patients who advised against the surgery did not resolve OSAHS nor had a difficult postoperative course.

20.6 Conclusion

The work that has been done shows that different surgical techniques, even if they have the same purpose, can have different characteristics in the aftercare.

There are better results with UPPP, AP, and BRP. UPPP is a less commonly used technique and AP is only performed under certain conditions (anterior-posterior palatal collapse). In conclusion, barbed reposition pharyngoplasty is the best choice for both postoperative outcomes and good patient compliance.

We know that our work should be extended to a multicenter study to have a larger number of patients in each group.

Therefore, we recommend the use of PPOPS as knowing the postoperative outcomes of the patients is useful for better surgical practice.

Although the BRP patients had slightly more discomfort after surgery, they recommended the procedure. This is the most important indicator of the success of the surgery, as the overall improvement in snoring and apnea outweighed their early postoperative suffering, which can be overcome with proper postoperative care and analgesia.

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21 BRP Vs Other Palate Procedures

Mohamed S. Rashwan

21.1 Introduction

The main purpose of this chapter is to explain why a sleep surgeon would prefer to choose the BRP instead of choosing any other technique in palatal surgeries for OSA patients. There are two main objectives in performing any kind of palatal surgeries: first to improve the palatal obstruction, second to treat the snoring. Meanwhile, the chosen technique should preserve the main anatomical and physiological functions of the soft palate and uvula.

Understanding the anatomy of the soft palate is very important while choosing our technique. The pterygomandibular raphe and pterygoid hamulus are very important surgical landmarks in BRP and ESP respectively. They are considered the lateral pillars for the surgery in order to improve the transversal collapse, which is the main concept for the lateral wall addressing techniques.

We tried to focus on the three most commonly performed techniques, which are BRP, ESP, and UPPP. Understanding the main differences between each of them will guide the surgeons in choosing the most suitable technique for their patients.

21.2 BRP Vs. Others

The BRP technique enables the sleep surgeon to achieve the two desired objectives. As a lateral wall addressing technique, BRP improves the latero-lateral in addition to the anteroposterior dimensions which will provide the patient with the widest targeted expansion in the retro-palatal space after the surgery. Since it's a

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_21

pharyngoplasty technique, there is no tissue resection at all from the free margin of the soft palate in addition to preserving the uvula, so avoiding two of the well-known complications of palatal surgeries which are velopharyngeal insufficiency and on the contrary velopharyngeal stenosis which can happen due to scaring. BRP also is a very good solution for snoring through inducing a sub-mucosal scaring along the line of the barbed sutures thus increasing the stiffness and in turn reducing the flutter of the soft palate. The surgery is very easy to be learnt by young surgeons and can be performed within 20–30 min depending on the surgeon [1].

Vicini et al. [1] tried to take the advantages of several issues in order to be able to address a new technique for palate surgery with especial concern to the lateral pharyngeal wall collapse. The authors were inspired by the relocation pharyngoplasty according to Li et al. [2] and got the advantage of using knotless bidirectional reabsorbable sutures introduced for similar purposes by Mantovani et al. [3]. They were able to modify their approach to the lateral pharyngeal wall/retropalatal airway switching from ESP to the relocation pharyngoplasty with some modifications.

The ESP technique works in a quite similar way to BRP through improving the transversal and anteroposterior dimensions of the retro-velar space. The main difference between both techniques is manipulating the palatopharyngeus muscle. In BRP the muscle is only weakened at the junction of the upper two-thirds and the lower one-third, while in ESP the muscle it is totally divided. Cutting the muscle makes the patient suffer from significant dysphagia in the early postoperative period. Moreover, the surgical technique is more difficult than BRP [4].

The UPPP technique used to be the most popular technique in terms of achieving rapid postoperative outcomes through reducing the anteroposterior collapse by resecting the uvula and part of the soft palate. The problem is in the postoperative complications passing through early velopharyngeal insufficiency to the late velopharyngeal stenosis. The surgeons faced two important questions; first: How much to resect? Second: How much the scar would affect the surgical outcome? A lot of surgeons were confronted with a very bad and difficult to treat complication which is velopharyngeal stenosis which happens due to the fibrous tissue induced by the surgery. Moreover, UPPP does not deal with the lateral pharyngeal wall which limits the desired retro-velar space expansion after the surgery. On the other hand, a lot of other techniques are far away from approaching the lateral pharyngeal wall like: LAUPS and UPFs, transpalatal advancement, and interstitial procedures (snoreplasty, RFVR, Pillar) [5].

The anterior palatoplasty (AP) technique still proves to be a good choice for simple snorers; also it can be combined with another lateral wall addressing technique like BRP in order to improve the postoperative snoring results, this point is in favor of BRP as it can be combined with another techniques [6].

21.3 Discussion

In 2017, Rashwan et al. [7] conducted a retrospective comparative study in order to compare the pre- and postoperative outcomes in single-level palatal surgeries including UPPP, ESP, and BRP with or without tonsillectomy, the results were

Table 21.1 Preoperative values (means ± standard deviation)

Group	AHI	ODI	ESS	LOS	*P*
BRP ESP	25.58 ± 14.60	24.39 ± 17.73	9.28 ± 3.10	80.56 ± 7.51	NS
UPPP	19.14 ± 9.66	16.30 ± 8.95	8.96 ± 3.36	86.52 ± 4.64	
	18.96 ± 17.79	17.56 ± 16.64	8.80 ± 3.23	77.60 ± 12.04	

No differences between groups were found. Quoted from Rashwan et al. [7]

Table 21.2 *P*-values of within groups analysis (Wilcoxon test)

Groups	Delta-AHI	Delta-ODI	Delta-ESS	Delta-LOS
BRP	<0.0001	0.0001	<0.0001	0.0018
ESP	<0.0001	0.0005	<0.0001	<0.0001
UPPP	<0.0001	<0.0001	0.0001	0.1084

Quoted from Rashwan et al. [7]

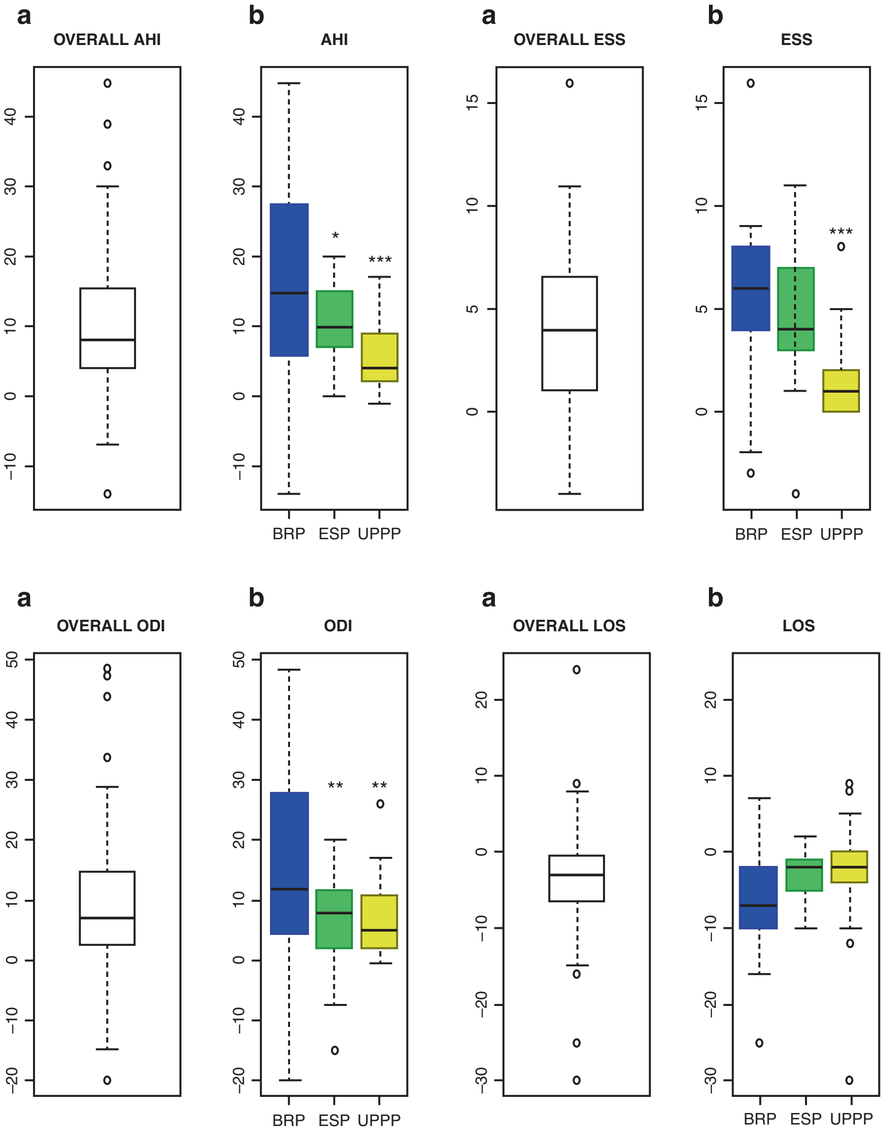
interesting as it showed: Preoperative values in all groups are presented in Table 21.1. Pre- and postoperative mean differences of AHI, ODI, and ESS values were calculated, and statistically significant reduction in these parameters was seen in the three groups ($P < 0.05$), Table 21.2. On the other hand, LOS decreased significantly in BRP and ESP groups, but not in UPPP group.

The results of the three groups analysis showed that AHI values decreased more significantly in BRP group than ESP (15.76 ± 14.5 vs. 10.13 ± 5.3; $P < 0.05$) and UPPP groups (15.76 ± 14.5 vs. 6.08 ± 5.5; $P < 0.0005$). The mean of differences of ODI values was higher in BRP group than UPPP group (15.09 ± 17.6 vs. 7.13 ± 6.8; $P < 0.0005$) but not than ESP group (15.09 ± 17.6 vs. 6.48 ± 7.9; $P > 0.05$). Furthermore, ESS values decreased more significantly in BRP group than ESP (5.52 ± 4.1 vs. 4.84 ± 3.3; $P < 0.005$) and UPPP groups (5.52 ± 4.1 vs. 1.36 ± 1.9; $P < 0.005$). Finally, the pre- and postoperative mean of differences of LOS values was not statistically significant among the three groups ($P > 0.05$), Graph 21.1. No statistically significant difference in the pre- and postoperative BMI data between the three groups was observed [7].

These results were in line with Pang et al. who could prove in 2016 through a systematic review and meta-analysis that ESP provides better outcomes than other traditional methods of palatal surgeries [8]. In line with these results, Vicini et al. concluded that as a part of multilevel procedure, including conventional nasal surgery and robotic surgery, ESP seems to be superior to UPPP [9].

In 2017, Cammaroto et al. could obtain comparable results in OSA patients treated with palatal surgery combined with transoral robotic surgery (TORS). The study did not show major difference between the BRP and the ESP groups, although both techniques proved to be more effective than UPPP in a multilevel setting [10].

In 2017, Rashwan et al. introduced a very simple tool for evaluating the outcomes of any kind of palate surgery in the patients' own views through answering 12 questions for the Palate Postoperative Problems Score (PPOPS) [11]. In 2019, Modica et al. used the PPOPS questionnaire to evaluate their patients and found better results in UPPP, AP, and BRP. UPPP is a less-used technique and AP is



Graph 21.1 (**a**) Overall mean of differences of AHI, ODI, ESS, and LOS values between post- and pre-surgery time. (**b**) Difference of AHI, ODI, ESS, and LOS values between post- and Presurgery time among three groups as visualized by the box plot. The bottom and top of the box are the first and the third quartiles, and the band inside the box is the median; whiskers represent 1° and 99° percentiles; values that are lower and greater are shown as circles, asterisks represent significance (*P*-value < 0.05). Quoted from Rashwan et al. [7]

performed only in specific conditions (anterioposterior palatal collapse). They stated that BRP is the best choice both for postoperative results and for good patient compliance [12].

BRP proved to be a quicker and easier technique and provided much less blood loss and better preservation of the mucosal and muscular tissues in comparison with ESP and, of course, UPPP [1, 10].

Better results were achieved from BRP and ESP over UPPP due to the lateral widening in the retro-palatal space provided by the upward and lateral rotation of the palatopharyngeus muscle. Moreover, BRP allows a more anterior soft palate displacement due to the lateral anchoring of the sutures on the pterygomandibular raphe.

Finally, the concentric scar that usually occurs in UPPP is better avoided in order to avoid one of the worst complications that is velopharyngeal stenosis as mentioned in several case reports [13].

21.4 Summary

OSA surgeons are trying to find the best physiological and tissue preserving technique while treating snoring and retro-palatal obstruction, which can be achieved by BRP. Moreover, they tried to avoid as much as they could an unexpected scar that could happen while manipulating the free margin of the soft palate in resective techniques such as LAUP or UPPP. The fibrous tissue induced by the surgery can eventually lead to a very undesired and difficult-to-treat complication like velopharyngeal stenosis and in turn more OSA.

21.5 Conclusions

- BRP is a safe and reliable soft palatal procedure.
- ESP still proves that it is a reliable technique.
- UPPP is no more the first technique of choice.

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22 Long-Term Functional Results of Barbed Reposition Pharyngoplasty Vs. Hyoid Suspension for Obstructive Sleep Apnea Hypopnea Syndrome

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The oropharyngeal district and its implications in the genesis of obstructive sleep apnea have been widely studied in several papers. In the field of palatal surgery, various techniques have been developed over the years. However, before the use of barbed sutures, not all oropharyngeal procedures achieved the desired success. Hypopharyngeal surgery was therefore born with the intention of assisting palatal surgery in the treatment of OSA.

One of the most common surgical procedure for OSAS is uvulo-palato-pharyngoplasty (UPPP), firstly described by Fujita in 1984 [1] and subsequently standardized by Fairbanks in 1999 [2]. UPPP's success rate as a stand-alone procedure ranges between 16% and 83% [3–5].

A major limitation of UPPP is represented by this wide range of success rates (16–83%) and by the numerous complications reported in the literature, mainly related to marked and disabling scarring. To overcome this wide range of success rate and the high risk of recurrence of UPPP, Mantovani et al. [6] introduced the barbed suture in palatal surgery in 2012 (Fig. 22.1).

This innovation was subsequently developed and improved by Vicini et al. [7] who introduced barbed reposition pharyngoplasty (BRP) in 2015. This technique displaces the palatopharyngeal muscle and so the posterior pillar anteriorly and laterally to enlarge the retropalatal space [7]. The crucial aspect is the use of pterygomandibular raphe as an anchor point for lateral traction. In this way and with the barbed suture, a global widening of all diameters is obtained.

Hypopharyngeal surgery finds its rationale to obviate the possibility of poor success after oropharyngeal surgery.

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_22

Fig. 22.1 UPPP wound healing

To date, hypopharyngeal surgery includes interventions that widen the airways from the outside (hyoid suspension) and procedures that intervene on the base of the tongue and reduce its lymphatic tissue (TORS). Although the first has been abandoned as a stand-alone procedure, it is currently indicated in association with specific palatal surgery.

Hyoid suspension (HS) was firstly described by Riley et al. and it involved the suspending of the hyoid bone to the inferior mandibular border using fascia lata [8]. Later on, Riley et al modified the technique and proposed to secure the hyoid bone to the thyroid cartilage below [9]. Subsequently, variable modifications to this technique have been proposed in literature mainly for improving the outcome and reducing its complications [10–13].

The hyoid suspension procedure is performed under general anesthesia. The skin incision is usually done between the body of the hyoid bone and the thyroid notch (Fig. 22.2).

The suprahyoid and subhyoid muscles are cut to increase the mobility of the hyoid bone, which is carefully tested considering how the hyoid moves forward and below the thyroid notch. Median strap muscle dissection is carried between two imaginary parasagittal planes crossing the lesser cornu of the hyoid bone (Fig. 22.3).

After having separated the strap muscles, the hyoid bone and the thyroid cartilage are exposed, and the thyrohyoid membrane is clearly defined (Figs. 22.4 and 22.5).

The body of the hyoid bone is wrapped with absorbable wire and then directed to the thyroid lamina (about 1/2 cm below the upper border) starting from lateral to the medial surface. After having reduced neck hyperextension, four stitches (two per side) are done between the hyoid bone and the thyroid notch (Fig. 22.6). The surgeon should control that the median points are placed below and forward compared to the lateral ones.

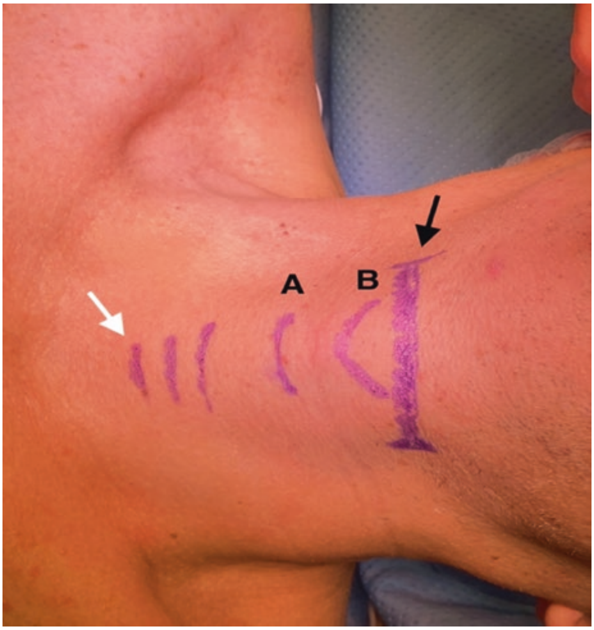

Fig. 22.2 White arrow: tracheal rings, A cricoid arch, B thyroid notch, black arrow: skin incision

Fig. 22.3 Resection of strap muscles

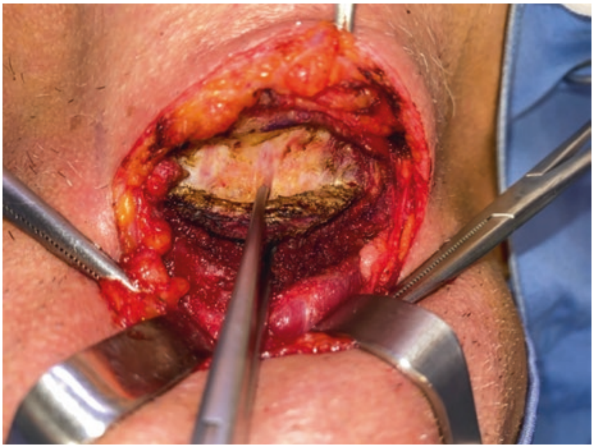

Fig. 22.4 Exposition of thyro-hyoid membrane

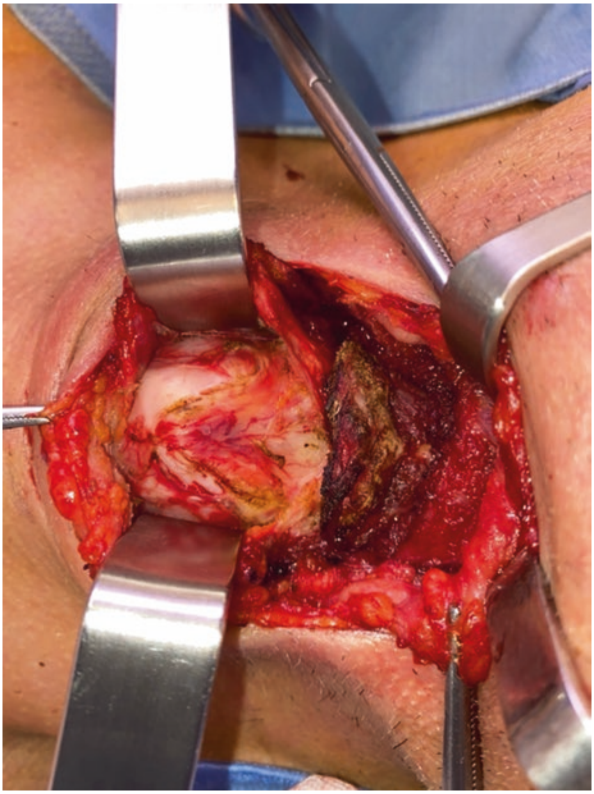

Fig. 22.5 Thyro-hyoid membrane completely exposed

Fig. 22.6 Four stiches (2 for each side)

In some cases, as proposed by the group of Professor Vicini, a third lateral point on each side that pulls the great horn of the hyoid bone forward and downwards can be placed. The rationale is to increase the tension of the lateral walls. In this phase the surgeon must pay attention to the contact between the needle and the hyoid to avoid accidental damage of the hypoglossal nerve. When the correct position of the thyroid cartilage below the hyoid bone has been tested, the surgeons could ensure the thyro-hyoido-pexy. It starts with double stitching of the antero-median parts followed by double stitching of the lateral ones. The tension of the lateral stitches should be lower than the tension of the anterior ones to avoid hyoid bone fractures (Fig. 22.7).

In terms of results, how important is the combination of palatal and hypopharyngeal surgery compared to isolated palatal surgery?

In a recent study conducted by our group at the ENT Clinic of the Azienda Policlinico Umberto I at "Sapienza University" of Rome, the results and outcomes of hyoid suspension in association with oropharyngeal surgery techniques such as UPPP and BRP have been investigated [14].

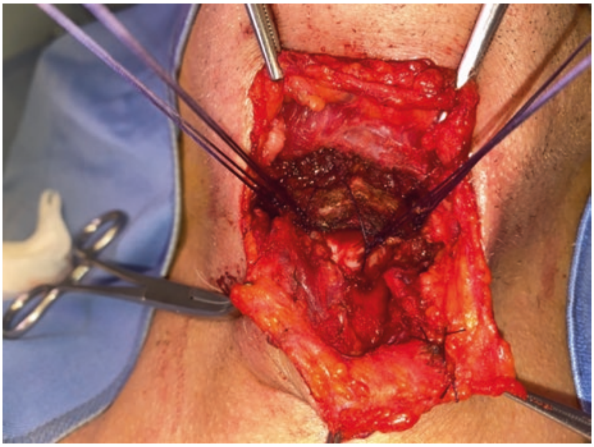

Fig. 22.7 Final thyro-hyoido-pexy

One-hundred twenty-two consecutive patients with a diagnosis of OSAS surgically treated between January 2015 and December 2018 were included.

All patients underwent complete preoperative otolaryngology evaluation, completed by endoscopic examination with Muller maneuver, polysomnography (PSG), and administration of Epworth Sleepiness Scale (ESS) questionnaire. All patients underwent UPPP according to Fairbanks or BRP technique according to Vicini, so patients were divided into two groups based on the surgical procedure (A: UPPP; B: BRP). The two procedures were performed as stand-alone or combined with hyoid suspension.

Complete ENT examination has been repeated 18 months after surgery and patients were classified based on PSG results as recovery, success, or failure.

What emerged is that BRP is more effective than UPPP (Fig. 22.8).

This could be related to the stronger and consequently more stable retraction of the pharyngeal soft tissue caused by the barbed suture of BRP. This is mainly due to the anchorage to the pterygomandibular raphe which determines a latero-lateral traction but also an enlargement of the anteroposterior space. It also allows a better preservation of the mucosa and muscle tissue, different from what happens with UPPP, where variable portions of palatal mucosa are removed. Notable is the fact that functional outcomes do not improve when BRP is performed together with hyoid suspension. Otherwise, UPPP showed a greater efficacy if performed with hyoid suspension. The possible explanation could be found analyzing the anatomical effect of UPPP and BRP performed alone. BRP, in fact, intrinsically allows, as already mentioned, a latero-lateral enlargement, an effect not possible with UPPP. The hyoid suspension works precisely to overcome this lack. It reduces the latero-lateral hypopharyngeal collapse and so it increases the transverse diameters of the upper pharynx [15] (Table 22.1)

Although pathophysiology of OSAS is still a matter of debate, the complexity of anatomical and functional factors that contributed to the genesis of apnea or hypopnea events has been widely accepted. Multilevel obstruction implies that the sole execution of UPPP is frequently inadequate.

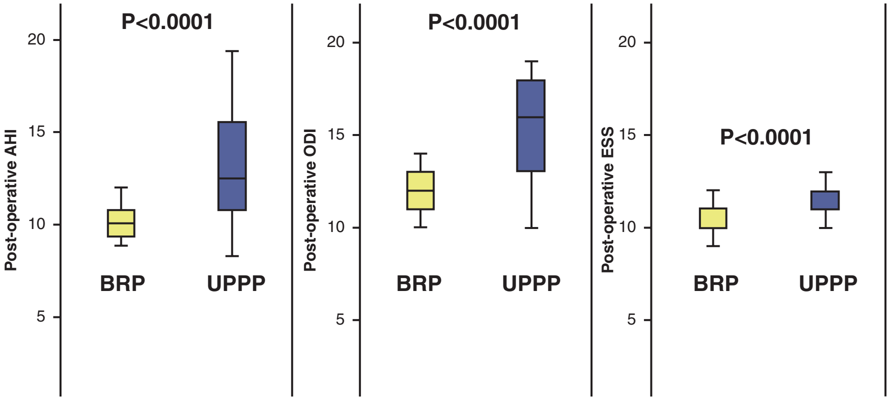

Fig. 22.8 Outcomes

Table 22.1 Outcomes of UPPP and BRP as standalone procedures and combined with HS

Variables	UPPP	UPPP+ HS	BRP	BRP+ HS	*p*
Delta BMI	−5	−8	−7	−15	0.01
Delta ESS	−7	−8	−17	−8	<0.001
Delta AHI	−42	−60	−66	−63	<0.001
Delta ODI	−26	−24	−31	−40	<0.001

The advent of barbed sutures in OSAS surgery and of BRP has led to a progressive reduction of use of invasive techniques with high risk of complications. So, the hyoid suspension has been progressively abandoned in the face of minimally invasive techniques that allow a multidimensional enlargement. In this context, BRP represents a safe, minimally invasive procedure, with a low risk of complications and with a rapid postoperative recovery.

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23 Outcome Predictors for Non-resective Pharyngoplasty in Obstructive Sleep Apnea-Hypopnea Syndrome

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Valeria Roustan, and Marco Barbieri

23.1 Outcomes in OSA Surgery

Obstructive sleep apnea (OSA) is a common sleep disorder whose prevalence is estimated between 2% and 4% of the adult population [1]. Such disease is characterized by the sleep-related collapse of the upper airway contributing to obstructive events during sleeping. Despite that such a disease itself does not directly cause acute events, it is in close relation with a significant increasing risk of cardiovascular diseases, as hypertension, myocardial ischemia, heart failure, and stroke, thus require an active treatment. Though the gold standard therapy is represented by continuous positive airway pressure (C-PAP) together with weight loss, surgical treatment, in not obese patients not compliant or refractory to C-PAP therapy, is nowadays an effective option with limited side effects.

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_23

The ultimate objective of any intervention is the reduction of the overall cardiovascular risk and the improvement of subjective quality of life (QoL), if compromised by the OSA condition [2].

According to the American Academy of Sleep Medicine Task Force recommendations a nocturnal respiratory polygraphy with apnea-hypopnea index (AHI) measurement should be performed [3] for the definition and grading of obstructive sleep apnea-hypopnea syndrome (OSAHS). OSAHS is defined by the evidence of an apnea hypopnea index (AHI) >5 and can be further classified into mild (AHI = 5–14), moderate (AHI = 15–30), and severe (AHI >30). Such parameter, despite not being itself a direct measure of the cardiovascular risk, is considered a good indicator: from studies over C-PAP treatments of OSHAS a deep post-treatment reduction of AHI values (95%) was shown to be capable in significant dropping the arterial blood pressure levels [4]. By contrast a reduction of 50% of the pretreatment AHI value was associated with a minimal reduction in arterial blood pressure only [4]. Such observation justifies the 50% reduction of AHI level as response to surgery in the most used classifications for postoperative outcome evaluation [5–7]. Moreover, if sleep-related complains are reported, the improvement of the subjective symptoms referred by the patients should also be considered as goal for every treatment interventions [2, 8].

Among the available methods for scoring and investigating the presence and grading of sleep-related symptoms referrable to the OSAHS condition, the Epworth Sleepiness Scale (ESS), with overall scores ranging from 0 to 24, is one of the most adopted questionnaires and adapted in several languages as Italian [9], German [10], French [11], Chinese [12], and Arabic [13].

23.2 Scoring Systems

The application of scoring systems for the comparison of pretreatment and post-treatment results of nocturnal respiratory polygraphy and QoL questionnaires is meaningful for several reasons. It permits the estimation of the post-intervention residual disease and symptomatology, the former correlated with the risk of cardiovascular events along time. Secondly, an accurate evaluation and definition of the response to therapy permits a self-judgment of results obtained, comparing different surgical techniques or same techniques across different centers. Moreover, the possibility to meta-analyze several studies permits to produce higher level of evidence, often limited by the retrospective setting of surgical studies, and possibly to improve and better tailor treatments for patients affected by OSAHS. Historically Sher in 1996 proposed a classification system comparing the pre- and posttreatment AHI results for the definition of treatment failure or success as following: success, or response to treatment, is defined achieving an $AHI_{post} < 20$ events/h together with at least a reduction of more than 50% of AHI_{pre} value (Table 23.1) [14]. Such simple scoring system has the advantage to be easily appliable and requires the evaluation of the posttreatment nocturnal respiratory polygraphy results alone. By contrast no

Table 23.1 Definitions of outcomes according to Sher or Vicini criteria

Outcome	Sher criteria [14]	Vicini criteria [7]
Cure	–	AHI <5 and ESS <10 and reduction of both by >50%
Success	AHI <20 and reduction of AHI by >50%	AHI <20 and ESS <10 and reduction of both by >50%
Failure	AHI ≥20 or reduction of AHI by ≤50%	AHI ≥20 or ESS ≥10 or reduction of both by ≤50%

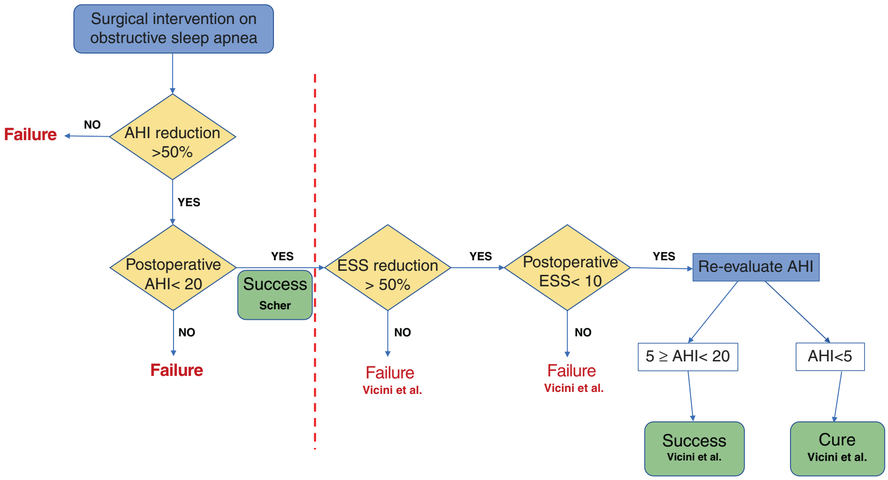

Fig. 23.1 The figure shows the flow chart to evaluate the surgical intervention on obstructive sleep apnea according to Vicini criteria [7]. The requirements on the left side of the red dotted line are considered sufficient to consider as a success a surgical treatment according to Sher criteria [14]

evaluation of any subjective feeling of the patient in terms of symptoms is done. Vicini et al., as previously suggested also by Sher itself, introduced a combined evaluation of the AHI results and the ESS one, at least obtaining a ternary scale defining Failure, Success and Cure (Table 23.1) [7]. As better shown by the tree-diagram in Fig. 23.1 a failure defined by Sher's criteria corresponds to a failure also applying the scale define by Vicini et al., whereas a successful treatment applying Sher criteria can potentially be either a failure, a success or a cure according to Vicini ones, as it is required both an improvement of the AHI parameter and of the ESS score. Thus, in comparing different studies and results is mandatory to carefully inspect the criteria applied for the outcome definition. Pang et al. proposed in 2016 the evaluation of the outcome testing 9 comprehensive parameters in the so-called SLEEP GOAL protocol [15]. The AHI and ESS evaluation are in agreement with other authors, furthermore, are added several other indicators of the QoL or cardiovascular risk change to better perform a multidimensional assessment [15]. Despite being a very ambitious aim, such multidimensional and complex evaluation is rarely applied in the current literature [16] and could be considered a future goal electronically and automatically integrating information derived from several types of assessments. In our opinion the classifier proposed by Vicini et al. [7], and already tested in cohorts of patients in the real-world experience [17, 18], permits an easy and not time-consuming judgment keeping information both from nocturnal respiratory polygraphy and from the ESS questionnaire, producing an easily understandable qualitative scale of results: failure, success, (no more continuous positive pressure needed), and cure [7].

23.3 Aims of Palatopharyngeal Surgery

It is widely accepted that the primary therapy, and gold standard, is C-PAP therapy, nevertheless the compliance to such treatment is still poor, exposing a patient affected by moderate or severe OSAS to a significant risk of cardiovascular diseases [19]. In this scenario alternative treatments are represented by oral appliances, craniofacial surgery or soft tissue surgery [20]. It was also shown that some interventions, as nasal surgery, could be a way to improve the compliance of C-PAP [20, 21]; this still need to be proved for the other available surgical or nonsurgical procedures.

The contemporary intervention management of OSAS is built both on physical examination with appropriate maneuvers and drug-induced sleep endoscopy (DISE), to detect the collapse sites and better tailor the treatment on the specific features of each patient, so candidate of achieving a good benefit from the intervention [22–25]. Given these assumptions further patients' factors, possibly influencing the overall outcome, are still under investigation. It is relevant, for the judgement of a specific surgical technique that the pre-requirements, seen as the indications for that specific technique, should be always met. In this view, the comparison of the results achievable by different surgical procedures should be done just among the same indication scenario (e.g., palatopharyngeal collapse, hypopharyngeal collapse, epiglottis collapse, craniofacial abnormalities).

Considering the clinical scenario of palatopharyngeal collapse several advancements and refinements of surgical techniques were done along the last decades, first understanding the benefit of the application of non-resective techniques, reducing the high complication and failure rates of uvulopalatopharyngoplasty [20, 26–28]. Moreover, the introduction of barbed sutures allowed the design of new roads for threads placement [29–32] to further treat each collapse pattern specifically (e.g., defined by the NOHA classification [24]). This led to the possibility to achieve the highest success rates, up to 89–90% [18, 29, 33, 34]. Despite obtaining such a good result, still a fraction of patients do not get enough improvement from the chosen intervention, with little improvement in polygraphy parameters or still having pathologic AHI values on posttreatment nocturnal polygraphy control.

23.4 Outcome Predictors

The identification of feature associated to treatment success could permit both to improve the patients' counseling and the decision-making process. Few authors searched for pretreatment or treatment-related features associated to the outcome, usually defined as success applying Sher or other criteria, in the specific setting of non-resective pharyngoplasty. The available evidence, coming also from other surgical interventions, support that a higher pretreatment body mass index (BMI) and a higher severity of the disease (e.g. higher pretreatment AHI values) are associated with worse outcomes [20, 35–38]. Furthermore, searching for anatomical characteristics, performing pretreatment computerized tomography (CT) evaluations, a narrower retropalatal airway was associated with higher posttreatment enlargement and with a higher rate of success [39, 40]. This observation supports the hypothesis that, as palatal/pharyngeal surgery is aimed at widening the pharyngeal airway at that level, the occurrence of a pathological, narrow, pretreatment space likely is one of the main pathological etiology of the disease that would improve after this correction.

In our experience, analyzing a cohort of patients affected by OSAS and having palatopharyngeal collapses evidenced at the DISE, we found that the pretreatment AHI values was associated with a worse outcome and 24.5 events/h was identified as the best cut-off, above which an optimum segregation of cured patients (below the cut-off) or not achieving more than a successful result (above the value) can be done. Interestingly the adoption of a barbed pharyngoplasty, compared to the ESP, was associated with a higher cure rate, supporting the relevance of the development of barbed-based techniques. Furthermore, a higher pre-treatment level of the ESS score was related to a higher chance of cure; this result should be carefully taken as the Vicini's classification was applied, requiring both an objective improvement of AHI values and subjective one of ESS score to the success/cure definition. Anyway, it is relevant that the presence of significant pretreatment sleep-related symptoms likely improve once a normalization of AHI values is achieved.

The routinely intraoperative measure of anatomical linear distances (Fig. 23.2), before and after palatopharyngeal surgery, permitted to test if such measures and / or their post-treatment variation were associated with the outcome [18]. Specifically, testing the success as endpoint, the increasing of the anteroposterior distance (A-P, linear distance between the posterior pharyngeal wall and the palate at the level of the base of the uvula) was the most significant variable, whose higher values were associated with a higher chance of success [18]. The best A-P cut-off of 8.5 mm could identify, with an area under the curve (AUC) of 0.95, a sensitivity of 93.5% and specificity of 87.5%, patients obtaining a successful posttreatment result [18]. The absence of a statistical association between BMI and poorer outcome, despite a trend for being a risk factor, is explainable by the criteria applied for surgical indication: presence of obesity with BMI > 35 was a contraindication for a surgical intervention.

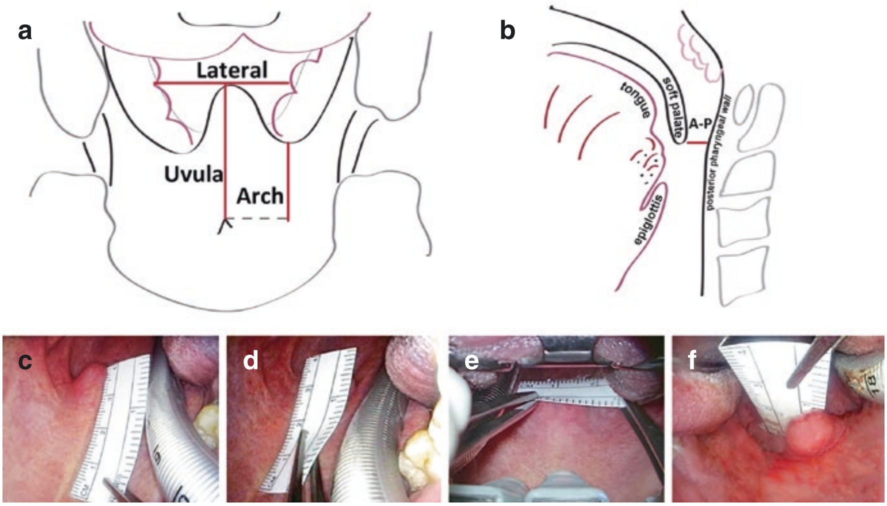

Fig. 23.2 Drawings showing intraoperative palatal measures: surgical view (**a**) and scheme on sagittal plane (**b**). Intraoperative view showing the measurement of intraoperative palatal and pharyngeal measures by a surgical ruler and mouth gag kept in place. Uvula length (**c**), Arch length (**d**), Lateral width (Lateral) (**e**); Anteroposterior width (A-P) (**f**)

The more favorable outcome observed in the group of patients treated with barbed pharyngoplasty, compared to ESP, is in agreement with a recent literature metanalysis supporting the usefulness, mini-invasiveness, and efficacy of barbed-based techniques [34].

Compared to the routine execution of pretreatment CT scans, the easy measuring of pharyngeal diameter and palatal measures is an easy, not expansive, nor invasive tool to improve the prediction of surgical success in applying non-resective pharyngoplasty procedures.

The future perspectives of routinely measuring such anatomical linear distances include the tailoring of the surgery itself to achieve a target change of such measures; anyway, further investigations are needed to external validate the usefulness of these measures for the prediction of the surgical success.

23.5 Tips and Traps

Aiming at obtaining reproducible and comparable measures, these should be taken once the definitive surgical position is achieved with the mouth gag in place. Two sets of identical measures should be taken just before the first surgical maneuver and after the placement of the last stitch.

The following linear measures can be obtained:

- Uvula length (Uvula): the distance between the posterior nasal spine and the apex of the uvula;
- Arch length (Arch): the distance between the palatal arch and the posterior end of the hard palate;
- Lateral width (Lateral): the distance from both posterior pillars measured on an axial plane at the level of the apex of the uvula;
- Anteroposterior width (A-P): distance from the posterior pharyngeal wall to the soft palate at the level of the uvula;

A regular surgical ruler, cut and customized, can be easily used, held by a long Kelly and/or forceps. If a nasotracheal intubation is chosen, a careful examination of the shape and tension of the palate should be done, mainly preoperatively, to avoid an overestimation of the A-P distance.

Given such measures, the estimation of the retropalatal area in squared centimeters can be done, modeled as a hemi-ellipse having semi-axes A-P width and Lateral/2 width, so that its value is defined by 12 *π*AP*Lateral.

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24 Long-Term Complications of Palate Surgery: An Update

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24.1 Introduction

Obstructive sleep apnea (OSA) is obstruction of the upper airway during sleep, this leads to complete or partial collapse of the upper airway leading to stoppages of breathing; resulting in sympathetic overdrive, hypertension, and hypoxemia. This obstruction of the upper airway may occur at the level of the velopharynx, the base of tongue, and/or the lateral pharyngeal walls; the collapse in OSA is often multilevel. Studies have shown that palatal collapse is the commonest site of obstruction, older palatal surgery techniques for OSA (namely the traditional uvulopalatopharyngoplasty) have been shown to have higher incidence of postoperative complications (high morbidity post-surgery). Older palatal surgery techniques were based on ablative methods that removed the uvula and resected a significant amount of soft palate; it is believed that these methods may cause a thick fibrotic scar on the palatal edge that would touch and abrade the base of tongue and result in a throat discomfort or lump in throat sensation. Newer palatal surgery techniques have more

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_24

reconstructive principles that address the lateral pharyngeal walls and preserve some or part of the uvula, and appear to have lesser long term postoperative morbidity. The authors present the long-term complications of newer palatal techniques in OSA surgery.

24.2 Methods

The authors conducted a nonrandomized retrospective multicenter clinical study of patients seen in the ENT office for snoring and/or symptoms of OSA. The inclusion criteria were OSA patients who had nose and palate surgery between 2009 to 2016, adult patients (>18 years old), AHI > 5, all Friedman stage, all Mallampati grades, single- or multilevel collapse, and all BMI (we excluded patients who had previous upper airway surgery and/or had any pillar implants or hypoglossal nerve implant inserted). Patients were recruited from seven tertiary clinical centers from six countries, namely Singapore, Canada, Italy, India, Hong Kong, and Korea. These patients had a comprehensive clinical assessment including a thorough physical examination, flexible awake naso-endoscopy, and an overnight polysomnography (PSG) pre-surgery and post-surgery. All patients also completed the Epworth Sleepiness Scale (ESS) and a visual analogue scale (VAS) for snoring before and after surgery. The bed partner completed a similar VAS scale for snoring (Table 24.1).

Clinical examination included height, weight, neck circumference, BMI, and blood pressure (systolic and diastolic); an endoscopic assessment of the nasal cavity, posterior nasal space, oropharyngeal area, soft palatal redundancy, uvula size and thickness, tonsillar size, and Mallampati grade. Flexible nasoendoscopy was performed for all patients, and collapse during a Mueller's maneuver was graded for the soft palate, lateral pharyngeal walls, and base of tongue.

The patients responded to a specific questionnaire based on their postoperative throat sensations (also known as symptom complaint), which included dry throat

Table 24.1 The various complaints from the various surgical techniques

	N	Dryness of throat	Lump in throat	Phlegm in throat	Throat scar	Swallowing discomfort	Symptom complaint
mUPPP	64	10	10	10	2	0	32
ESP	50	0	0	0	0	0	0
BRP	40	2	1	4	0	0	7
FEP	34	0	0	2	1	0	3
UPF	11	0	5	0	0	0	5
SP	9	4	5	4	4	0	17
RP	8	1	3	2	1	1	8
ZPP	1	0	1	0	0	0	1

ESP expansion sphincter pharyngoplasty, *FEP* functional expansion pharyngoplasty, *BRP* barbed reposition pharyngoplasty, *mUPPP* modified uvulopalatopharyngoplasty, *UPF* uvulopalatal flap, *SP* suspension palatoplasty, *RP* relocation pharyngoplasty, *ZPP* Z-palatoplasty feeling, lump in throat sensation/foreign body sensation, feeling of throat phlegm, feeling of throat scar sensation, difficulty swallowing, taste disturbance, and voice change. All patients rated the frequency of these sensations based on (a) constantly—felt almost all the time, (b) occasionally—felt at least twice per week, (c) rarely—felt once or twice per year only and (d) never—never felt these symptoms before.

Surgeries were based on previously described palatal surgery techniques. The expansion sphincter pharyngoplasty (ESP) as described by Pang et al. [1], the functional expansion pharyngoplasty (FEP) as described by Sorrenti et al. [2], the barbed reposition pharyngoplasty (BRP) introduced by Vicini et al. [3], the modified uvulopalatopharyngoplasty (mUPPP) (uvular preservation or recreation surgically) as described by Li et al. [4], the uvulopalatal flap (UPF) as proposed by Neruntarat [5], the suspension palatoplasty (SP) described by Li et al. [6], the relocation pharyngoplasty (RP) as introduced by Li et al. [7], and the Z-palatoplasty (ZPP) as described by Friedman et al. [8].

24.3 Results

The authors described 187 males and 30 females (65 Caucasian and 152 Asian), with a mean age of 43.9 ± 12.5 years and mean BMI 25.9 ± 4.7. The mean preoperative AHI was 30.5 ± 19.1, while the mean preoperative LSAT was 75.2 ± 19.2%. The mean follow-up was 41.3 months.

There was a total of 217 palatal procedures: 50 expansion sphincter pharyngoplasties (ESP), 34 functional expansion pharyngoplasties (FEP), 40 barbed reposition pharyngoplasties (BRP), 64 modified uvulopalatopharyngoplasties (mUPPP), 11 uvulopalatal flaps (UPF), 9 suspension pharyngoplasties (SP), 8 relocation pharyngoplasties (RP), and 1 z-pharyngoplasty (ZPP).

The complications that were deemed clinically significant were those that occurred "constantly" (almost daily) and "occasionally" (at least twice per week), which were included as a "postoperative complication." These were dry throat in 17 patients (17/217, 7.8%), throat lump feeling in 25 patients (25/217, 11.5%), throat phlegm feeling in 22 patients (22/217, 10.1%), feeling of throat scar in 8 patients (8/217, 3.7%), and difficulty swallowing food only in 1 patient (1/217, 0.5%). Of the 17 patients who had dry throat complaint, 2 were constant (1 SP, 1 RP) and 15 were occasional (10 mUPPP, 3 SP, 2 BRP). Of the 25 patients with the throat lump feeling, 4 were constant (3 RP, one ZPP) and 21 were occasional (10 mUPPP, 5 SP, 5 UPF, 1 BRP). Of the 22 patients with the throat phlegm feeling, 4 were constant (2 SP, 2 RP) and 18 were occasional (10 mUPPP, 4 BRP, 2 FEP, 2 SP). Of the 8 patients who had a feeling of the throat scar, 8 were occasional (4 SP, 2 mUPPP, 1 FEP, 1 RP) and none were constant. Only one patient had occasional feeling of difficulty swallowing, and this patient had an RP done. There were no patients who reported taste disturbance nor voice change.

The number of complication complaints (defined as a complaint of any one of the above symptoms) per procedure was:

(a) Modified uvulopalatopharyngoplasty (mUPPP) (64 procedures)—32 symptom complaints
(b) Expansion sphincter pharyngoplasty (ESP) (50 procedures)—0 symptom complaints
(c) Barbed relocation pharyngoplasty (BRP) (40 procedures)—7 symptom complaints
(d) Functional expansion pharyngoplasty (FEP) (34 procedures)—3 symptom complaints
(e) Uvulopalatal flap (UVPF) (11 procedures)—5 symptom complaints
(f) Suspension pharyngoplasty (SP) (9 procedures)—17 symptom complaints
(g) Relocation pharyngoplasty (RP) (8 procedures)—8 symptom complaints
(h) Z-palatoplasty (ZPP) (1 procedure)—1 symptom complaint

It appeared that the procedures with the highest symptom complaints were the modified uvulopalatopharyngoplasty, the suspension pharyngoplasty, and the relocation pharyngoplasty, while the lowest symptom complaint was the expansion sphincter pharyngoplasty, followed by the barbed pharyngoplasty and functional expansion pharyngoplasty.

24.4 Discussion

It is understood that the older palatal surgery techniques involved resecting soft palatal and uvular tissue, whereas newer reconstructive palatal surgery techniques entailed more mucosal sparing and functional methods. Post-UPPP long-term follow-up studies are not common. As there is a reporter bias that tends not to report poor results or complications of surgery, there have been not many papers that report long-term side effects of the older traditional UPPP technique. Two such papers showed high incidence of long-term complications following these older palatal techniques; Goh et al. reported in a small group of 49 OSA patients (10-to-17-year phone call follow-up) a high incidence of 28.5% of velopharyngeal incompetence (VPI) after the traditional ablative UPPP (from 1980 to 1983) [9]. Varendh et al. [10] showed in 144 OSA patients who had the traditional UPPP done between 1985–1991, 20-year follow-up that 14% had persistent VPI, swallowing issues 20%, voice change 12%, and oral cavity pain 12%. However, Tang et al. [11] performed a systemic review on 24 studies (1-year follow-up), with 191 OSA patients who had either the traditional UPPP or the mUPPP done; they showed a lower incidence of VPI at 8.1%, difficulty swallowing (17.7%), dry pharynx (23.4%), voice changes (9.5%), and taste disturbances (8.2%), with the commonest complication being foreign body sensation/lump in throat sensation at 31.2%. Choi et al. [12] showed in 87 OSA (5-year follow-up) patients who had the traditional UPPP and UVP done a low incidence of VPI 4.6%, foreign body sensation 10.3%, dry throat 3.4%, voice change 2.3%, and speech change 1.1%. Friberg et al. [13] had 65 OSA patients who were followed up for 2 years, they reported a taste disturbance at 4%, mild symptoms like throat phlegm or foreign body sensation in throat were 10%, moderate in 15%, and severe symptoms in 6%.

The authors found that the commonest long-term complication (over a 41.3-month follow-up period) was a lump in throat sensation/foreign body sensation at 11.5%, throat phlegm feeling 10.1%, dry throat feeling 7.8%, and feeling of the throat scar 3.7%. The mUPPP had the largest contribution to the pool of complications; hence, the authors excluded the mUPPP postoperative data and found that the long-term complications were lower at lump in throat sensation/foreign body sensation at 9.8%, throat phlegm feeling 7.8%, dry throat feeling 4.6%, and feeling of the throat scar 3.9%.

Analyzing the individual symptom complaint per procedure, it appears that the highest symptom complaint per se would be the modified uvulopalatopharyngoplasty (mUPPP), followed by the suspension pharyngoplasty (SP) and relocation pharyngoplasty (RP). The authors acknowledge that theoretically, these newer techniques tend to preserve more mucosa, preserve, or create a new uvula, address the lateral pharyngeal wall muscles mainly (instead of the soft palate) and tend not to resect or ablate useful healthy soft tissue and mucosa.

It is important to recognize some short comings of the review:

(a) Due to the small sample size in the study, individual procedure numbers tend to be smaller, hence, less statistical significance.
(b) Multicenter trials have different surgeons with different techniques doing the similar procedure might produce different results
(c) The mean follow-up was 42 months; however, longer studies with more patients might be useful to further delineate the exact long-term complication rates
(d) The "newer" palatal surgery techniques based on the fact that most reconstructive palatal techniques and lateral pharyngeal wall techniques were introduced after the year 2006–2007 onwards.

24.5 Conclusion

It appears that the newer generation palate surgeries have lower long-term complication rates compared to the older traditional UPPP techniques.

Acknowledgments There are no financial disclosures and no conflict of interest for all the above authors.

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Barbed Pharyngoplasty in Revision Surgery

25

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25.1 Introduction

Sleep surgery has been recently facing a deep revolution, shifting from aggressive ablative procedures to more conservative, reconstructive, and tailored techniques.

Regarding soft-palate surgery, the application of the relocation philosophy and the introduction of barbed sutures have allowed to take a significant step toward an effective individualized targeted treatment [1, 2].

The surgical principle applied in the more classic palatal techniques adopted for simple snoring and obstructive sleep apnea (OSA) treatment was basically the shortening of the soft palate (uvulopalatopharyngoplasty (UPPP) and laser-assisted uvulopalatoplasy (LAUP)) or the lifting of the uvula and soft palate [uvulopalatal flap (UPF)].

However, a better understanding of upper airway collapse patterns during sleep has led sleep surgeons to focus their attention on the pivotal role of lateral pharyngeal wall in the genesis of pathologic collapses [3]. In this sense, drug-induced sleep endoscopy (DISE) has certainly allowed a deeper comprehension of the multilevel pharyngeal collapse mechanisms [4].

In particular, sleep surgery paradigm has been changing from pure expansion of upper airway by means of surgical ablative procedures to the stiffening of the pharyngeal lateral wall by means of reconstructive surgical techniques.

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*, https://doi.org/10.1007/978-3-030-96169-5_25

Several new palatal surgical techniques for snoring and OSA have been developed to primarily address the lateral pharyngeal wall and to laterally enlarge the oropharyngeal entrance: lateral pharyngoplasty [5], expansion sphincter pharyngoplasty (ESP) [6] and barbed repositioning pharyngoplasty (BRP) [1] are some of the most recently proposed techniques.

The majority of these procedures are based on the anterior and lateral repositioning of the palato-pharyngeus muscle, with the purpose of achieving the stability of the lateral pharyngeal walls during sleep by means of muscular manipulation [7].

Therefore choosing the most appropriate pharyngeal technique seems to be pivotal for reaching satisfactory results in retropalatal collapses, and this appears possibly more important in case of a revision surgery.

25.2 Soft Palate Functional Anatomy

According to Olszewska et al., even static anatomy of the palate plays a significant role on upper airway collapses [8]. Three palate patterns are described by these authors:

(A) Oblique palate: characterized by an obtuse angle between hard and soft palate. In this case, the retropalatal airway size is larger in its anterior-posterior dimension at the hard palate, genu, and velum levels. The axial shape appears more circular with a circular collapse pattern.

(C) Vertical palate: the narrowing of the airway is more evident at the genu and velum levels. It is related to an acute angle between hard and soft palate. The airway shape is coronal with an anteroposterior pattern of collapse.

(B) Intermediate palate: it presents a narrowing at the genu and velum levels, with an intermediate collapse pattern between circular and anteroposterior.

Woodson et al. highlighted that each palate shape might require a specific surgical approach. In particular, the effectiveness of soft palate surgery was significantly higher in oblique soft palates (with a circular collapse pattern). On the other hand, patients with vertical palates and an anteroposterior collapse pattern reported the lowest success rate [9, 10].

25.2.1 Clinical Examination in Barbed Pharyngoplasty Revision Surgery

Sleep surgeons should perform a complete clinical examination of OSA patients experiencing a failure after palate surgery in order to identify the motivations. For instance, physicians should particularly focus on the volume of the tongue in relation with soft palate, differentiating primary from secondary soft palate collapses. Moreover, a hypopharyngeal obstruction due to obstructive hypertrophic lymphatic tissue at base of the tongue should be excluded.

Moreover, DISE is mandatory in all treatment failures and, especially, in surgical failures. In fact, DISE allows physicians to confirm the presence of primary soft palate collapse, analyze the patterns of palatal collapses, and eventually investigate the presence of a primary epiglottic collapse [11–13].

25.3 Barbed Pharyngoplasties

The need for more effective and less harmful palate procedures has led sleep surgeons to develop new techniques and technologies.

In this sense the application of barbed sutures for the treatment of snoring and OSA by Mantovani is certainly a milestone.

"Barbed Roman curtain technique" (BRBT), introduced in 2013, is a suspension technique characterized by three innovative principles [2]:

1. the complete preservation of the oropharyngeal fibro-muscular structures;
2. the identification of specific fibro-osseous sockets as suspension points (the posterior nasal spine, the hamuli pterygoidei, and the pterygo-mandibular raphes);
3. the use of knotless barbed sutures to stabilize the fibro-muscular structure of the soft palate and of the lateral pharyngeal walls in the suspension points.

Since 2013, other barbed procedures were developed, such as:

1. barbed repositioning pharyngoplasty by Vicini et al. (BRP) [14]
2. anterior barbed pharyngoplasty (BAPh) [15]
3. Alianza (BRBT + anterior pharyngolasty) [16]
4. barbed functional expansion pharyngoplasty [17]

Each technique has specific indications based on the results of the physical examination of the upper aerodigestive tract by means of static and dynamic awake endoscopy and, possibly, by means of DISE.

All these procedures create a tense structure, interposed between fixed structures (bone and fibrous) and soft tissues (muscles and mucous membranes), with the aim of transferring to the latter the properties of rigidity of the former, preventing that during sleep, when the component loses muscle tone, the pharyngeal walls collapse in the inspiratory phase, giving rise to phenomena such as snoring and apnea. This intratissual tensile structure is made with special self-locking threads, called "spined sutures," which have the prerogative to act without the need to tie.

These techniques do not involve any section or removal of muscle tissue, fully respecting the complex functions of this apparatus. The barbed wires used are made of reabsorbable material, polydioxanone, therefore destined to be completely absorbed in about 6 months, leaving fibrous scars, which have the task of maintaining the results achieved by the intervention over time.

These characteristics make barbed procedures extremely practical, customizable, and repeatable, and for these reasons they could represent the right compromise in revision interventions for simple snoring and OSA.

Furthermore, being substantially conservative interventions, they allow further revisions, avoiding the most common complications due to classic ablative palatal surgery.

There are several possible scenarios for opting for a revision barbed palate surgery. In all of these it is fundamental knowing how soft palate and lateral pharyngeal walls were manipulated and if the landmarks for each potential revision technique were preserved [7].

25.4 Failure of Conventional Surgeries in OSA Patients

Despite a success rate not higher than 40–60% [18] and high risk of significant complications, UPPP is still the most performed palate surgery for the treatment of OSA worldwide and several variations of this technique have been presented in the literature. Aggressive resection of the soft palate and pharyngeal structures during UPPP could cause major complications in up to 58% of patients, such as velopharyngeal insufficiency, dysphagia, persistent dryness, globus sensation, vocal changes and oropharyngeal stenosis, the least due to aberrant scarring [19].

In these post-UPPP scenarios, performing a revision surgery could be particularly challenging and the selection of the most appropriate technique and the most suitable candidates appears to be the real key to significantly increasing the chances of success.

The preservation of palatopharyngeal muscle and the absence of excessive scarring with medialization of posterior pillars are mandatory if a lateral barbed pharyngoplasty is planned (BRP, BRBT, or barbed functional expansion pharyngoplasty).

On the other hand, an anterior palatoplasty might not help to achieve optimal outcomes being failures of UPPP mostly due to a persistent lateral pharyngeal walls collapse or tongue collapses.

25.5 Failure of Lateral Pharyngoplasty

Considering the reduced odds of success of revision pharyngoplasty, performing a new barbed procedure is however possible. Preservation of palatopharyngeal muscle is fundamental in order to guarantee the anchoring of lateral pharyngeal walls to stable structures such as pterigomandibular raphe and pterigoid hamulus.

For instance, performing a BRP in patients previously treated with other lateral pharyngoplasties might not be possible. In ESP palatopharyngeal muscle is resected caudally and tied around the hamulus. Therefore surgeons might not be able to adequately dissect the muscle and reposition it as described by Vicini et al.

BRP might also be performed more than once in OSA patients experiencing long-term failures probably due to the loss of adequate muscular tension, previously obtained after first surgery (Figs. 25.1, 25.2, 25.3, and 25.4).

Fig. 25.1 Preoperative picture showing a soft palate previously treated with BRP

Fig. 25.2 Disepithelization of tonsillar areas and surgical landmarks for BRP

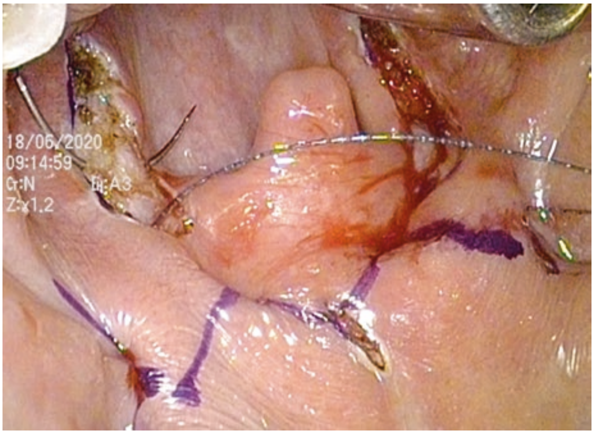

Fig. 25.3 Palato-pharyngeal muscle manipulation during surgery

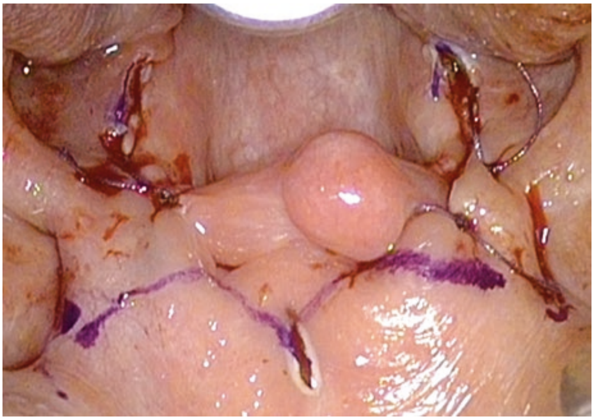

Fig. 25.4 Intraoperative look after completion after a revision of BRP

25.6 Failure of Anterior Palatoplasty

Performing barbed pharyngeal surgeries is technically possible in patients previously treated with an anterior palatoplasty.

As previously mentioned, the role of lateral pharyngeal walls in the genesis of pathological collapses has been largely demonstrated. For this reason, anterior palatoplasties could not be sufficiently effective for the treatment of OSA in some specific patterns of patients. In these circumstances, BRP, Alianza, and other lateral barbed pharyngoplasties certainly represent valid therapeutic options.

However, barbed anterior palatoplasties could also be performed in patients complaining postsurgical persistence of snoring, potentially leading to a more effective stiffening of soft palate.

25.7 Conclusions

Recent meta-analysis reported an improvement of postoperative polisomnographic indexes after ESP and BRP [20]. These improvements are basically due to the modification of surgical philosophy, which shifted from ablative to reconstructive surgical procedures. Nevertheless, conventional UPPP remains the most performed palatal surgery in OSA patients, worldwide. Palatal revision surgery remains a challenge, but BRP could represent a valid and effective surgical option. A complete clinical examination and the use of DISE are highly recommended for patients selection and identification of the most appropriate surgical technique. In the future, a better and easier identification of anatomical and non-anatomical endotypes as well as a precise and standardized methodology of surgical patient selection will probably decrease the number of palatal surgery failure.

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26 Barbed Pharyngoplasties in Multilevel Surgery Including TransOral Robotic Surgery (TORS)

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26.1 Introduction

Since the introduction of uvulopalatopharyngoplasty (UPPP) by Fujita et al. [1], surgical treatment for patients with obstructive sleep apnea (OSA) was mainly directed at the level of the soft palate which was thought to be the main area of obstruction. However, the effectiveness of this surgical procedure was brought into question in a large meta-analysis that showed UPPP to be effective in less than 50% of the cases [2]. At the same time, surgeons began to realize that OSA is a disease entity that is much more complex than previously appreciated. The obstruction may involve multiple levels of the upper airway from the level of nose down to glottis. Fujita et al. [3] presented classification of the upper airway into different levels of obstruction either retropalatal, retrolingual or combined retropalatal and retrolingual obstruction. On the basis of this distinction, Riley et al. [4] defined the term and concept of multilevel surgery.

Base of tongue (BOT) resection for treatment of OSA is not a new concept. Recognizing the important contribution of BOT obstruction in OSA, Fujita first reported on the usage of carbon dioxide laser for midline glossectomy in 12 patients [5]. Perhaps due to the complexity of the surgery and the potential for major complications, this procedure never became popular.

Nowadays, surgical management of OSA is most successfully achieved by multilevel surgery [6]. This was confirmed after thorough understanding of the complexity of airway obstruction by drug-induced sleep endoscopy (DISE) that showed

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_26

that the hypopharynx and base of tongue, not only the palate, are important anatomic components of obstruction in OSA [7]. In addition, the lateral collapse of the airway has been noted to be of particular significance in recalcitrant cases.

As a result of this increased awareness, multiple surgical approaches directed at the BOT level have been described. These techniques included mandibulotomy with genioglossus advancement [8], hyoid advancement [9], Repose® tongue suspension [10], radiofrequency base of tongue reduction (RFBOT) [11], submucosal minimally invasive lingual excision (SMILE) [12], coblation-assisted lingual tonsillectomy [13, 14], midline laser glossectomy [3], maxillo-mandibular advancement (MMA) [4], TransOral Robotic Surgery (TORS) [15, 16], and implanted upper airway stimulation device [17]. Reports of surgical effectiveness of these procedures vary widely in the literature and are difficult to interpret due to the wide variety of diagnostic and surgical procedures employed, the complexity and uniqueness of the upper airway in individual patients, as well as the varying experience of the reporting surgeons [18].

26.2 Historical Background

Vicini et al. [15, 16] reported on their experience with 20 patients who underwent TransOral Robotic Surgery (TORS) with tongue base reduction (TBR) concomitantly with multiple other procedures such as septoplasty, supraglottoplasty, UPPP, turbinate reduction, and ethmoidectomy. In this group, the mean AHI dropped from 36.3 ± 21.1 to 16.4 ± 15.2 ($P = 0.0001$), and mean ESS dropped from 12.6 ± 4.4 to 7.7 ± 3.3 postoperatively ($P = 0.0003$) [6]. The failures regarding the AHI, in this group, were assumed to be related to the fact that the oropharyngeal region was not treated properly. More specifically, in certain patient, TORS was failed because the epiglottis and the oropharynx were not addressed surgically; so after TORS, these two regions were still seen to have collapsed [16].

Friedman reported on 27 patients who underwent robotic-assisted midline glossectomy in conjunction with ZPP. The mean AHI dropped from 54.6 ± 21.8 to 18.6 ± 9.1 ($P < 0.001$) and mean ESS dropped from 14.4 ± 4.5 to 5.4 ± 3.1 postoperatively ($P < 0.001$) [19].

Since 2008 till 2014, more than 100 cases were published in seven single center reports in Literature. In 2014 the first multicenter study about TORS in which a cohort of 243 cases from 7 groups in 5 different countries was available [20].

In 2015, Thaler et al. [6] conducted a study using DISE to show the importance of adding TORS in a multilevel procedure on degree of reduction of AHI. Seventy-five patients completed DISE, OSA TORS, UPPP, and pre- and postoperative polysomnography. The mean age of patients was 49.7 years; the mean preoperative BMI was 32.3. Patients were further divided into two groups for purposes of comparison: those who had had no prior pharyngeal surgery and those who had had prior pharyngeal surgery (this included tonsillectomy and UPPP). The best outcomes were obtained in those patients who had had no prior surgery and who underwent OSA TORS in addition to UPPP (67% reduction in AHI vs. 33% for UPPP alone). OSA

TORS provided an additional 24% reduction in AHI. The preoperative versus postoperative difference in AHI was statistically significant for the entire group as well as the previously unoperated group [6].

26.3 Effect of Palate Surgery on TORS Results

The overall number of TORS for OSA cases, since March 2008 till April 2021, is about 360 operated by Forlì Hospital in Italy. For the first cases, all the palate surgeries were treated performing a classic uvulopalatopharyngoplasty (UPPP). Since June 2010, the UPPP palate technique has mainly been replaced by a modified expansion sphincter pharyngoplasty, inspired by the Pang-Woodson expansion sphincter pharyngoplasty technique [21]. For that reason, the Italian group had the unique opportunity to compare the contribution of two different palate surgeries with the overall outcome of a multisite one-step procedure including a TORS TBR [22].

26.3.1 Expansion Sphincter Pharyngoplasty (ESP)

Two groups of 12 severe OSAHS cases each were sorted according to the primary selection criteria of statistically comparable preoperative AHI (about 38 AHI for both). The two groups were also reasonably matched for sex, age, body mass index (BMI), and volume of removed TB tissue. Both groups underwent multilevel surgery of the upper airway including nose surgery if required, TORS TBR according to the Vicini (C.V.)–Montevecchi (F.M.) technique [15]. Meanwhile, Group A cases underwent UPPP procedure according to the Fairbanks technique while Group B cases underwent ESP according to Pang–Woodson [21] with minimal modifications as palate surgery. These modifications include: (1) blunt palate tunneling without mucosal incisions; (2) posterior pillar flap tip suturing in order to prevent a possible tearing of the tip by the pulling suture; and (3) systematic use of a second intermediate suturing of the flap under direct visual control [22].

The purpose of that study was to show the superiority of ESP compared to the traditional UPPP as a multilevel procedure. The most striking finding is a postoperative AHI of 9.9 ± 8.6 SD for the ESP group versus a postoperative AHI of 19.8 ± 14.1 SD for the UPPP group. Pre-postoperative comparison, in terms of AHI, reached the statistical significance for both techniques. Comparison between UPPP and expansion sphincter pharyngoplasty, in terms of AHI improvement, is at the limit of statistical significance [22].

The authors concluded that the palate component of multilevel procedure, ESP, including conventional nose surgery and robotically assisted TB and supraglottic surgery, seems to be superior to UPPP. Functional and objective superiority (as measured by postoperative polysomnography) and better acceptance by the patient (less pain and less late discomfort) seem to balance the longer surgical time, the higher technical complexity, and the longer learning curve [22].

26.3.2 Barbed Reposition Pharyngoplasty (BRP)

A systematic retrospective review of the literature, the analysis of our cases and a targeted cadaver dissection study prompted us to modify our approach to lateral pharyngeal wall switching from ESP to relocation pharyngoplasty (RP) according to Li et al. [23] with some modifications inspired to different experiences in the area [24]; We introduced (1)“Barbed” which refers to the use of knotless bidirectional reabsorbable sutures introduced for similar purposes by Mantovani et al. [25] (2)“Reposition pharyngoplasty” because it displaces the posterior pillar (palatopharyngeal muscle) in a more lateral and anterior position to enlarge the oropharyngeal inlet as well as the retropalatal space. (3) Suspension of the posterior pillar to the pterygomandibular raphe. (4) Initial weakening of the inferior aspect of the palatopharyngeal muscle. The multiple lateral sustaining suture loops of BRP proved to be more stable than the single pulling tip suture of ESP, with no risk of tearing the muscle fibers losing the entire pulling force.

In a preliminary study of ten adult male patients were included (three patients underwent BRP combined with TORS with tongue base reduction, seven BRP with nasal and/or hyoid surgery) with mean age 53.4 ± 12.4, mean BMI 28.5 ± 3.6. The pre-operative AHI was reduced from 43.65 ± 26.83 to 13.57 ± 15.41 ($P = 0.007$), and the preoperative ESS was reduced from 11.6 ± 4.8 to 4.3 ± 2 ($P < 0.01$) [24].

The most important advantages of this palatal technique are the stability of the new wide retropalatal space that was confirmed by fiber-optic examination 6 months post-operative. In addition, this technique is easily teachable, operative time decreased over the course of the study with steady decrease in operative time to as short as 20 min as observed by our surgical team. Finally, pain as assessed by VAS and dysphagia as assessed by MD-Anderson dysphagia questionnaire showed that this technique is well accepted by patients who underwent multiple surgical trauma at multiple levels of upper airway collapse [24, 26].

26.4 Conclusions

Barbed reposition pharyngoplasty proved to be an easy to learn, quick, safe, and effective palatopharyngeal procedure standing alone or as a part of multilevel surgery for sleep apnea. The key points that must be considered are the use of a knotless reabsorbable suture technology, the minimal and targeted muscle manipulation, the use of the pterygomandibular raphe as sustaining structure. The minimal muscle and mucosa resection and the absence of knots in the pharynx are well accepted by the patients in terms of invasiveness. The minimal required manipulations and the knotless technique mean for the not experienced surgeon a technique easy to learn, quick, and safe to perform, including inside a simultaneous multilevel procedure [27, 28].

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Myofunctional Therapy as a Postoperative Adjuvant Treatment to Single Level Velopharyngeal Surgery

27

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27.1 Introduction

Orofacial myofunctional therapy (OMFT) has been described since 1918 to improve mandibular growth, nasal breathing, and the development of muscles of face [1]. Afterwards OMFT has been proposed as a complementary treatment for obstructive sleep apnea (OSA) since the 1990s.

OSA in adults is a multifactorial disease, which pathogenesis seems to be related to anatomical and non-anatomical factors: upper airway collapsibility, changes in activity of oropharyngeal muscles during sleep, low respiratory arousal threshold, an oversensitive ventilatory control system and a poor muscle responsiveness to negative pharyngeal pressure play cumulative role to the apnea genesis and maintenance [2]. The dilator muscles of the upper airway play a key role in maintaining an open airway during sleep and are essential to the maintenance of pharyngeal patency. Dysfunction and imbalance of oropharyngeal muscles, especially of the genioglossus muscle, could be responsible for an airway collapse [3]. For this reason, recent studies have explored the effects of oropharyngeal exercises as a complementary technique for treating OSA.

OMFT is composed by several combinations of oropharyngeal exercises, mainly delivered by speech pathologists [4]. These exercises vary regarding the time frame of treatment and can include isotonic and isometric contractions involving several muscles of mouth, pharynx, and upper respiratory tract.

Patients must work on functions such as speaking, breathing, blowing, sucking, chewing and swallowing, repeating exercises a variable number of times.

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_27

The aim of OMFT therapy is to improve the functioning of muscles involved in the patency of the airway, increasing its tone, tension, and mobility and remodeling the disposition of fat pads.

OMFT was firstly developed to promote an appropriate performance of respiration, mastication, deglutition, and speech. The starting point was the recognition that an equilibrium of orofacial muscles was required to prevent and correct malocclusion. Chronic mouth breathing patients have been long treated by speech-language pathologists due to orofacial myofunctional impairments [5].

In OSA patients, orofacial and pharyngeal muscles dysfunction and impaired oropharyngeal control are possible contributing factors to airway collapse, in the presence of anatomical predisposition.

27.2 Myofunctional Assessment

To evaluate the efficacy of OMFT, is essential to have validated tools that enable identifying, classifying, and grading changes in muscles and functions status prior and after the intervention.

However, currently are available different tools, without widely and common application throughout studies.

The first tool described was the orofacial myofunctional evaluation with scores (OMES) [6]. His aim was to evaluate which musculature and pharyngeal function is impaired in order to plan the best rehabilitation strategy. The OMES was later modified and expanded. Nevertheless, this newer tool is very time consuming because of having too many items. Another objective measure of muscle condition can be obtained from electromyography [7].

Villa and colleagues [8] proposed objective evaluation of tongue strength and endurance through the Iowa Oral Performance Instrument (IOPI), a kind of tongue bulb pressure gauge. The IOPI measures the pressure in kilopascals (kPa) that an individual can produce by pressing a standardized air-filled tongue bulb. With simple exercises the author was able to measure tongue strength, tongue peak pressure, and endurance.

27.3 Pathogenetic Basis, Exercises, and Classifications

OMFT can be classified according to the different anatomical segments and functions targeted [9]: soft palate elevation, extrinsic and intrinsic muscles of tongue, genioglossus muscle, lip, and check (see Figs. 27.1 and 27.2 at the end of the article).

Exercises may target soft palate elevation, involving in this function the recruitment of tensor and levator veli palatini, palatopharyngeal, and palatoglossus muscles. These exercises have the purpose of increase the tone of elongated and floppy soft palate and uvula, and strengthening the lateral pharyngeal walls muscles, involved in airway patency (Figs. 27.3 and 27.4). Other targets muscles may be

Soft palate	Elevation of the soft palate with intermittent vocalization (using open vowels) - isotonic exercise
	Elevation of the soft palate with intermittent vocalization (using open vowels) - isometric exercise
	Elevate soft palate and uvula without pronouncing a vowel (to obtain control and coordination of the movement).
	Elevate soft palate with a yawn.
	Produce sounds with uvula like snoring with open mouth.
	Produce sounds with tongue and uvula by contracting the dorsum of tongue and the velum.
Tongue	Brush the superior surface of the tongue while it is positioned in the floor of the mouth.
	Brush the lateral surface of the tongue while it is positioned on the floor of the mouth.
	Place the tip of the tongue against the anterior part of the hard palate, then slide the tongue backward slowly.
	Place the tip of the tongue as posteriorly as possible on the palate.
	Press the entire tongue upward against the palate and maintain this position.
	Place the tongue tip against the inferior incisive teeth and force the posterior region of the tongue downward.
	Stick the tongue in and out form mouth and push as far as possible.
	Protrude the tongue tip forward just in front of the lips, without touching teeth or lips and without deviation in front of a mirror.
	Spread center of the tongue, so the sides of the tongue touch the bottom of the upper teeth
	Protrude the tongue outside the mouth and move the tip up and down.
	Move the tongue to the corner of the mouth and keep it pointed on both sides.
	Move the tongue from corner-go-corner as quickly as possible.
	Move the tongue all around the lips in a circle, the repeat quickly.
	Stick out the tongue to reach the chin with the tip, then hold at the farthest extension.
	Protrude the tongue. Keep a spoon and hold upright against the tip of tongue. Then try to push it away while your hand holds the spoon in place.
	Spin the tongue in the oral vestibule.

Fig. 27.1 Exercises for soft palate elevation, extrinsic and intrinsic muscles of tongue

tongue extrinsic and intrinsic muscles, involved in tongue repositioning and remodeling (Figs. 27.5 and 27.6).

The dimensions of the tongue, not only in terms of area and volume but also in terms of fat percentage, are strongly associated to upper airway collapsibility. The accumulation of fat in the lingual muscle fibers, can reduce the response and the activity of the muscle during sleep and consequently compromise the right lingual position and the posterior pharyngeal space [10]. The OMFT, reducing parapharyngeal fat pads and the lowering the amount fat in the muscle fibers of the tongue, induce upper airway remodeling and improve improvement in the airway patency during sleep.

The genioglossus muscle is the most important extrinsic tongue muscle involved in airway patency [11], and its activity correlates strongly with negative pharyngeal pressures measured at the epiglottis [12].

The deposition of fat along the muscle fibers may also explain the reduction of function of muscles.

Other exercises aim to prevent mouth opening and restoring nasal breathing, targeting muscles involved in lip tone and labial seal.

Facial	Contract the lips (orbicularis oris muscle) with the mouth closed (isometric exercise).
	For orbicularis oris muscle: open and close the jaw slowly and widely but keeping the lips in contact.
	Pucker the lips in a kiss-like movement.
	Spread the lips into a smile (as biggest and exaggerate as possible).
	Pucker lips-hold-smile-hold.
	Maintain the mouth wide open, then pucker the lips, without closing the jaws.
	Close the lips firmly, and then make a “slurping” noise, as if sipping a drink.
	Perform repetitive suction movements contracting only the buccinators (isotonic exercise).
	Perform suction movements contracting only the buccinators, holding this position (isometric exercise).
	Suck air from a syringe (20mL).
	Recruitment of the buccinator muscle against the finger that is introduced into the oral cavity.
	Isometric exercise: Elevate and hold the mouth angle muscle (right and left).
	Isotonic exercise: elevation of the mouth angle muscle, ten repetition from each side (right and left).
	Lateral jaw movements with alternating elevation of the mouth angle muscle.
	Open and close mouth as quickly as you can, making sure your lips close each time
	Say “Ma” quickly and repeatedly. Do the same with different syllables (e.g. “La” and “Kala”).
	Sing the vowels “A–e–i–O–U” and “U–O–I–E–A” as loud as possible.
Stomato-gnatic function	Suction: suck different fluids (e.g. water, yogurt, etc.) with straw, narrowing it with fingers alternatively.
	Breathing and speech together while sitting:
	Forced nasal inspiration and oral expiration in conjunction with phonation of open vowels.
	Balloon inflation with prolonged nasal inspiration and then forced blowing.
	Swallowing and chewing: Alternate bilateral chewing.
	Deglutition: with the tongue positioned on the palate swallow with occluded teeth and without perioral muscle contraction.
	Swallow with the tongue tip between teeth anteriorly while.

Fig. 27.2 Exercises for lips and checks

Fig. 27.3 Soft palate resting position

Fig. 27.4 Soft palate isotonic exercise. The patient pronounces the vowel "A" intermittently to elevate soft palate and uvula

Fig. 27.5 Tongue isometric exercise. The patient puts the tongue against the superior tooth with opened mouth, then shifts the tongue posteriorly, keeping the contact with the hard palate

Fig. 27.6 Isometric contraction of the tongue. The tongue is pushed against the hard palate and maintained in this position

Suprahyoid muscles, especially geniohyoid and mylohyoid, are involved in elevation of tongue, due to the displacement of the hyoid bone in an anterior (geniohyoid) and upper direction (mylohyoid). Exercises involving these muscles could help to elevate the hyoid bone, usually lowered in OSA patients. The elevation of hyoid muscle collaborates to shorten the airway, preventing its collapse.

27.4 Protocols

Several exercises have been previously described, but it is important to determine whether the goal is strengthening, building endurance, restoring optimal muscle tone, or facilitating speed/range/power during movement [13].

Consequently, must be take into account not only exercise load and intensity, but also frequency and duration of repetition of each exercise and of the whole treatment [14].

The training method for OMFT for OSA patients impacts the effectiveness of those exercises [15].

To better compare results of OMFT, is fundamental schedule detailed protocols and strict adherence to it.

Speech therapist must guarantee the correct performance of each exercise and must visit patients with pre-established cadence.

To overcome these advantages, O'Connor-Reina C. and colleagues [16] developed a new mobile health app that use a smartphone to teach patients to perform these exercises. This app could not only measure the adherence to therapy, but also the objective increase in muscle oropharyngeal tone during time.

27.5 Efficacy

Rueda J.R. and colleagues [17] compared the efficacy of myofunctional therapy with other interventions. In adults, compared to CPAP alone, OMFT may increase AHI and result in little to no difference in daytime sleepiness. Compared to CPAP plus OMFT, OMFT may results in little to no difference in daytime sleepiness and may increase AHI. Compared to respiratory exercises plus nasal dilator strips, OMFT may results in little to no difference in daytime sleepiness and AHI, with probably increasing sleep quality slightly.

Compared to standard medical treatment, OMFT may reduce daytime sleepiness and increase sleep quality. OMFT is more effective than sham therapy or waiting list in reducing daytime sleepiness and apnea-hypopnea index, with contradictory results about sleep quality.

In children, compared to nasal washing alone, adding OMFT may results in little to no difference in AHI.

The length of the interventions and follow up-periods were short (less than 4 months), with no data about the potential effects on medium and long term.

Small bony framework, including retrognathia and maxillary hypoplasia, may result in lower effectiveness [18]. The main disadvantages of myofunctional therapy are the poor adherence to therapy and the absence of objective feedback. Speech therapist cannot be present during each day of exercises, and nobody can assess if exercises are correctly done in time and strength.

27.6 OMFT and Surgery

A wide range of surgical procedures are described to treat OSA. Tailored surgical approach is recommended, but during last decades more demolitive approaches have been replaced by less invasive procedures.

Less aggressive approaches guaranteed preservation of pharyngeal function, but often structures and functions need a re-education after surgery to enhance and sustain outcomes. Surgical outcomes commonly decline with time because of maturity of operation scar, relaxation on tightening procedure and weakening of muscle tone [19].

OMFT has to be seen as part of integrated treatment with positional therapies, body weight reduction, and cognitive behavior therapy [15]. OMFT could be applied both on muscular treated segment (e.g. soft palate) and not treated (facial and tongue muscles). In both cases, OMFT should not be administered before the restoration of surgical wound, that usually occur within 1 month.

Currently, no data are available on OMFT as adjuvant treatment in palatal surgery for OSA. Further studies must focus on this topic.

Ideally, OMFT is a reversible therapy, without side effects, being potentially administered from the beginning in the therapeutic plan or as a rescue therapy after surgery in case of residual OSA.

Only a few papers are available on this topic, on OMFT in adjunction of adenotonsillectomy exclusively in pediatric population. OMFT in children is recommended in adjunction to surgery if myofunctional status did not showed a spontaneous improvement within a 6-month-period [20]. D.A. Bueno et al. [21] suggested that, even though usually adenotonsillectomy improves OMES scores, children who have not presented complete myofunctional recovery after the first month of follow-up should benefit from speech therapy.

In this perspective, a fundamental role is achieved by preoperative evaluation and uniformity in the preoperative assessment is needed.

OMFT could be seen as adjuvant therapy in adult OSAS population with three different purposes: first, as rescue or adjuvant therapy for failure/uncomplete success of palatal surgery in terms of AHI and symptoms. Lots of studies showed the positive effects of OMFT, especially on symptoms. The effectiveness on AHI remains debated, but lower than CPAP (see efficacy paragraph).

Secondly, to recover complications of palatal surgery, especially on swallow disorders. OSAS patients have increased prevalence in swallowing dysfunction [22]. It is possible that the bolus leakage is caused by a failure in the swallowing reflex triggering, dependent by local neuronal damage caused by the snoring vibration trauma [23, 24]. In patients with OSAS the upper-airway mucosal sensory function in the oropharynx is impaired and could alter pharyngeal function during swallowing and the normal coordination between breathing and swallowing while awake and asleep [25]. Consequently, ENT specialist should evaluate swallowing condition in patients with OSAS before surgery, to better identify which patients would be predisposed to swallowing symptoms after surgery and if these signs were already present [26]. Post-operative edema, pain, inflammation, changes in muscle orientation, contraction, and manipulation could be determinants of swallowing worsening with the development of signs of hypopharyngeal stasis and laryngeal penetration. Scar maturation and inflammation also alter the oropharyngeal sensibility as well as to the manipulation of the oropharyngeal musculature. Swallowing patterns could be modified postoperatively, with a prolonged hyoid movement time, the decreased movement of the velum and decreased pharyngeal constriction time [27]. Studies indicate that many of the postoperative changes tend to resolve by a month after surgery.

List but not least, myofunctional therapy may represents also as a physical therapy after surgery to speed up the functional recovery. Tonsillectomy usually is needed immediately prior to the palatal surgery. Tonsillectomy must spare the most palatopharyngeal and palatoglossus muscles, but often their function is impaired. In ESP and FEP techniques, palatoglossus muscle is cut and rotate laterally and superiorly, losing its original function and orientation. In these kinds of surgery, innervation and re-innervation phenomena are possible, but these muscles need a stimulation from the beginning. OMFT could be seen as part of rehabilitation programs. Further studies must evaluate the feasibility and if the early movement during scar formation could increase the bleeding risk.

The muscles on which the therapy is addressed are mainly the tensor veli palatini and levator veli palatini, palatopharyngeus, superior constrictor of the pharynx and muscularis uvulae.

27.7 Limitations and Future Perspectives

The objective measurement of adherence to the therapy is difficult, often derived by self-reported adherence diary [18].

Another limitation is that efficacy OMFT therapy nowadays could be calculated by OMES scores or similar tools, nevertheless the efficacy of these therapies on OSA are evaluated by AHI or OSA symptoms. Surgery negatively impacts myofunctional status in the early post-operative stages, so it's difficult to separately differentiate the functional outcomes.

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Modified BRP and Different Palate Techniques to Treat Oropharyngeal Collapse

28

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28.1 Introduction

The use of barbed sutures in pharyngeal surgery for sleep apnea or snoring is our preferred type of suture since 2015, after learning the barbed reposition pharyngoplasty (BRP) technique from Vicini et al. [1]. Although we started performing the same BRP at the beginning, based on the knowledge of the coaxial tubes theory proposed by Mantovani [2], we decided to perform more loops in both the lateral pharyngeal wall (LPW) and soft palate. In the coaxial tube theory, the upper airway (UA) is composed of an external rigid tube made of osseous and fibrous tissue that create an arch, composed of the palatine aponeurosis (that it is thicker in the junction to the hard palate), the pterygoid hamulus, and the pterygomandibular raphe. A soft inner tube, encompassing static elements (mucosa, submucosa, fat, lymphatic tissue, and minor salivary glands) interact with dynamic elements, the UA muscles.

Supplementary Information The online version contains supplementary material available at [https://doi.org/10.1007/978-3-030-96169-5_28].

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_28

By using sutures inside the soft tissue, a tensile structure anchored in the inner tube to specific areas of the rigid outer tube, is created in order to prevent pathological collapsibility.

Moreover, our group extracts supratonsillar fat, as is performed in the Australian pharyngoplasty [3] and in the relocation pharyngoplasty [4], to help to elevate the soft palate.

28.2 Surgical Technique (Video 28.1)

Surgery begins with a tonsillectomy or LPW mucosectomy. We perform this with monopolar electrocautery using a needle tip, power set at 12 Watt. Maximum care is mandatory in the extracapsular dissection to preserve the palatoglossus (PG) and the palatopharyngeus (PP) muscles intact (Fig. 28.1). In case of previous tonsillectomy, a vertical incision in the mucosa covering PP muscle is performed in order to expose the PP muscle fibers. Usually, this incision is enough to perform the technique, but sometimes a complete mucosectomy of the anterior part of the PP is needed.

The next step is the supratonsillar fat extraction. A 4–5 mm arcuate incision is made in the soft palate following the superior edge of the PG muscle. It is useful to pay attention to the change in pattern of the capillary vessels to deduce where the PG ends. Nowadays we extract the fat with the electrocautery needle tip, but initial cases were performed with cold dissection using Metzenbaum scissors. We believe that for the novel surgeon, it is safer this cold dissection in order to preserve the palatal muscles until they get familiarized with the anatomy (Fig. 28.2). As Olzewska and Woodson point out [5], the fat is located in the lateral palatal space. This space has a pyramidal shape (wider at its base near the tonsil and narrower superiorly at

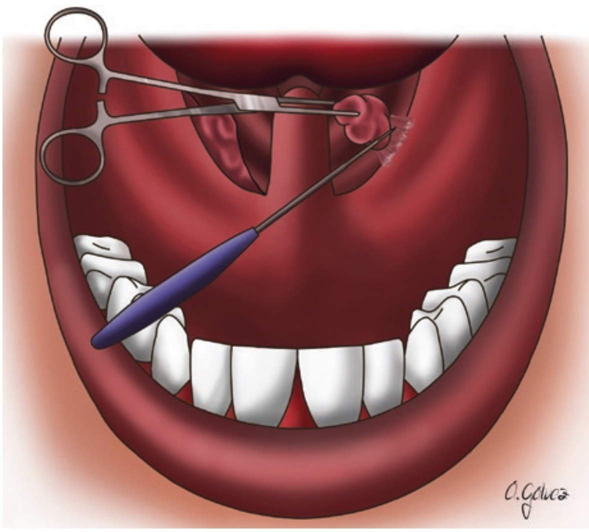

Fig. 28.1 Tonsillectomy respecting the pharyngeal muscles

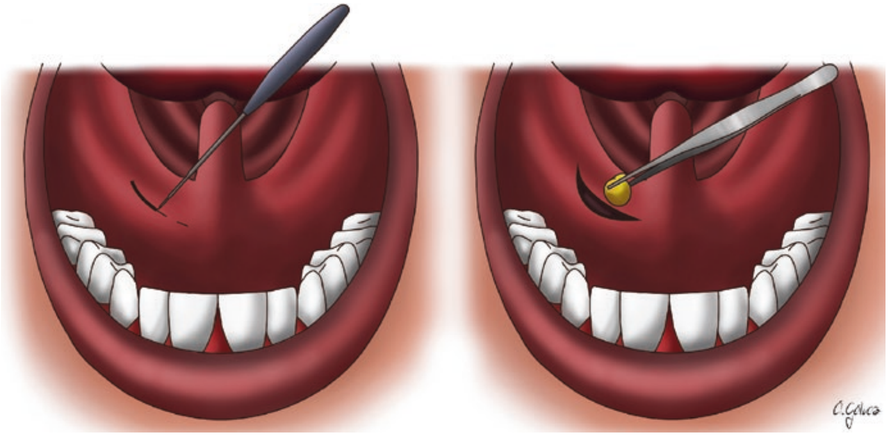

Fig. 28.2 Incision and extraction of the supratonsillar fat

the hamulus). The limits of this space are: Inferiorly—the tonsil and deep fibers of the PG; medially—the proximal intravelar segment of the PP; superiorly—the hamulus; and laterally—the superior constrictor (SC) which separates it from the pterygomandibular space and the parapharyngeal space. Ventrally, it is bounded by the superficial fibers of the PG and the ventral palatal mucosa.

Once the fat is extracted, we begin with the barbed suture steps, using a PDO spiral, barbed, bi-directional, 26 mm needle and 2/0 thread 40 × 40 cm. Although no study has been performed, the authors believe that thicker threads increase patients discomfort in the postoperative period, as well as making it more difficult to perform more loops. At every point the thread should not be exposed, ergo the entrance of the needle must be exactly at the same entry point.

We start in the midline 2 mm below the junction between the soft and hard palate. The tip of the needle is directed towards the hole created after the fat excision. It is important to try to reach the palatal fascia located in the posterior part, therefore, the needle must pass through the muscle deeply. From the supratonsillar hole we go to the hamulus and from there to the tonsillar fossa (Fig. 28.3).

The first loop in the LPW is done in the upper part of the PP grabbing as much muscle as possible and from there to the upper part of the pterigomandibular raphe. This creates some tension and relocates the muscle in a more anterior and lateral position, also creating some upwards tension due to the oblique direction of the thread. The supratonsillar hole is slightly reduced due to this movement. If the soft palate is long, it may be necessary to do this stitch in two times, the middle step is to exit through the hole. Afterwards another second loop is undertaken, starting from the raphe to the PP, at a slightly inferior position regarding the previous loop and again to the raphe. This second loop will help to secure the tension of the PP. Finally, a third loop in the middle third of the tonsillar fossa to the lower part of the raphe, but far away from the mandible, to avoid damage to the lingual nerve. Stretching of the thread to increase tension is repeated each time the thread comes

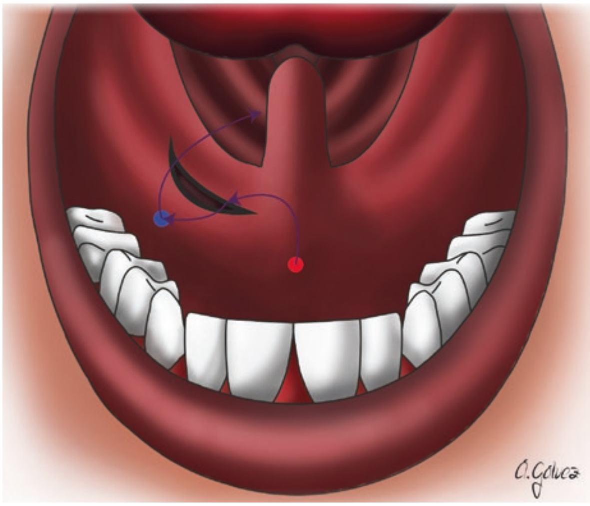

Fig. 28.3 First steps of the bidirectional barbed suture: Starting in the midline at the junction of the hard palate, towards the hamulus passing through the supratonsillar hole created from the fat excision

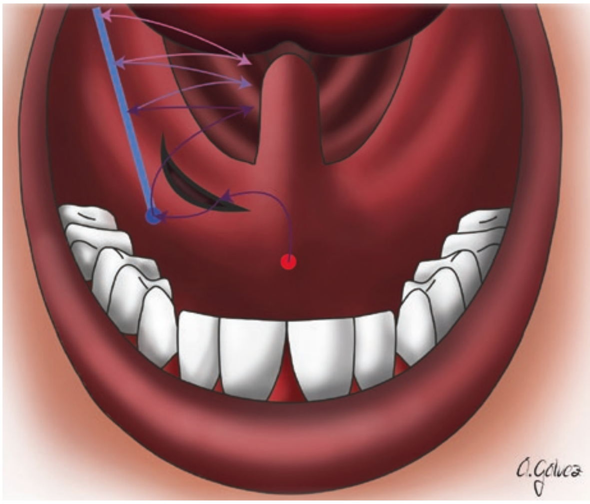

Fig. 28.4 The three loops in the PP to the raphe, in cephalo-caudal direction creating tension in the LPW

out of the raphe. The rationale for the three loops is to give more support and stability to the PP. Once the suture is reabsorbed, fibrous scar tissue will help maintain the lateralization and the tension, helping sustain long-time results (Fig. 28.4).

We execute the other side in the same manner with the other needle of the bidirectional thread.

On completion of LPW suture, we direct the needle towards the soft palate, and complete stitches in a zig-zag fashion grabbing the horizontal part of the PP and the PG in the lower end to the upper part of the soft palate close to its junction with the palatal bone. Once again, each time the needle exits near the hard palate, tension is applied to the thread so that the whole palate is elevated, and the supratonsillar fat

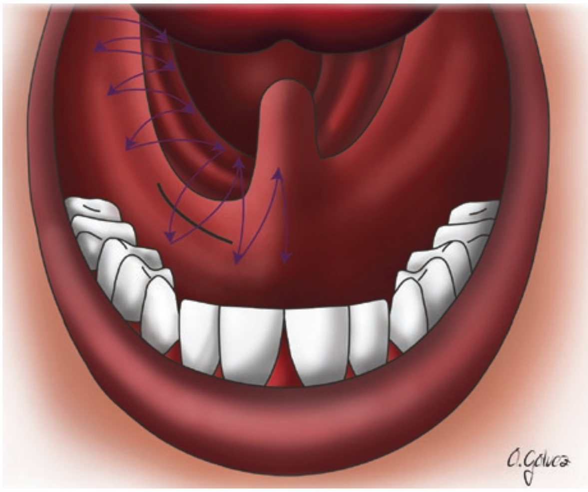

Fig. 28.5 Zig-zag suture in the soft palate that closes the supratonsillar fat incision and helps to open the retrovelar space

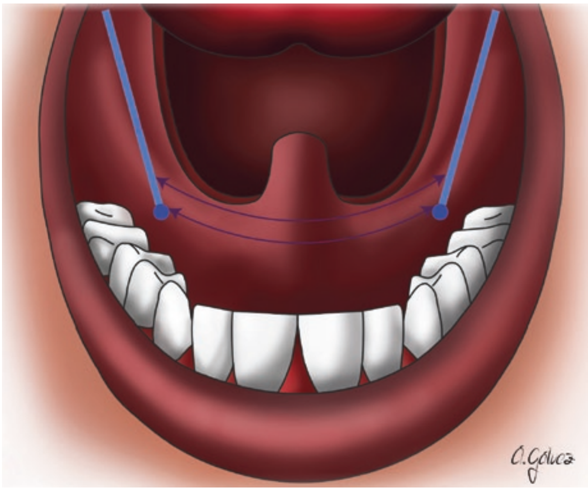

Fig. 28.6 Raphe-to-raphe stitches at two levels

incision can be closed. These stitches should be performed in a way that the whole thickness of the soft palate is passed without trespassing the nasopharyngeal mucosa. Each needle does these zig-zag stitches in their respective sides (Fig. 28.5).

Finally, a raphe-to-raphe stitch at two levels, one with each needle. Entering in the lower part of the soft palate, grabbing the uvula at its base and superiorly in the middle of the soft palate (Fig. 28.6).

At the end of the surgery, you can observe that the soft palate and the lateral pharyngeal walls have expanded, fixed outwards with the barbed suture much like a corset, decreasing collapsibility. Moreover, the retrovelar space is increased (Video 28.2).

28.3 Modifications to the Technique Described

Using barbed sutures is advantageous because it avoids knots, allows tension throughout all the passages, and confers versatility. Therefore, it is possible to adapt the technique according to the patient's anatomy and the type of collapse observed in DISE.

If the PP muscle is very thick and does not move laterally easily, it can be partially sectioned in the middle of the tonsillar fossa with a horizontal incision (using monopolar diathermy) as it is performed in the BRP. It can also be detached from the superior constrictor muscle if needed, but it should not be separated from the pharyngeal mucosa. If the muscle is thin, we believe that these steps are not needed as the muscle can be easily moved with the forceps after the tonsillectomy. Nevertheless, if the muscle is thick, we strongly recommend cutting it and separate it from the constrictor because it can easily relapse in the immediate postoperative days.

If the uvula is long, we cut the tip. We prefer and recommend this be executed after the tonsillectomy, before the palatal work, so the actual size can be appreciated before the edema of the surgery changes its size. This avoids cutting it too short after the edema sets in.

In case there are important webs, we perform two paravalvular incisions in the PP until we reach the lower part of the PG muscle. When we do these incisions, we always cut the tip of the uvula, as the uvula becomes elongated with these release incisions (Fig. 28.7).

In non-obese patients, we do not perform the incisions to extract the supratonsillar fat because there is very little fat, and we believe that it does not reduce the lateral palatal space as much as it does when the patient is overweight or obese. Nevertheless, we still perform the zig-zag stitches in the soft palate because it helps increase the anteroposterior space in the pharynx.

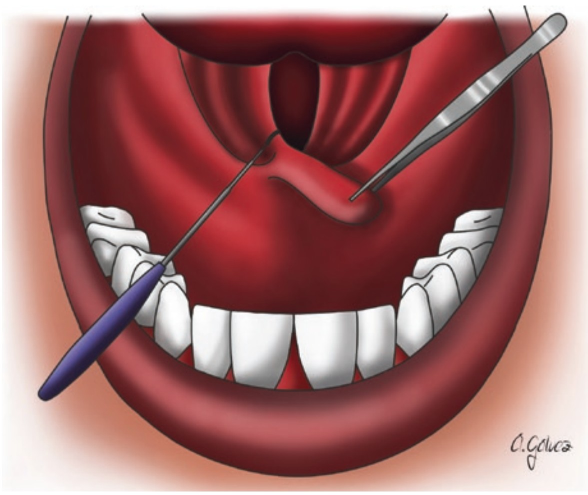

Fig. 28.7 Incision in the lower part of the PP until the PG is reached that is performed when there are important webs

It has been described that up to 36% of the patients do not possess the so called pterigomandibular raphe, not showing a ligament structure [6]. That is the reason why we incorporate two more stitches to create this anchorage to the PP muscle. We perform a stitch from the hamulus to the lower part of the raphe and again to the hamulus so we can start the stitches of the PP from a higher position to have more tension.

28.4 Results

Since 2015, the barbed suture pharyngoplasty has been the technique used in our department at the Hospital Universitario Dr. Peset in Valencia, Spain.

Currently, we have 68 people with pre and postoperative sleep study performed between 4 and 6 months after the surgery. We have performed a statistical study in order to know the results of the technique.

The mean age was 41.29 (SD 11.64) years, 76.5% were male and 23.5% female, body mass index (BMI) 28.37 (SD 4.40) kg/m^2. 45.59% of the cases had also nasal surgery and 25% of the patients had multilevel surgery (Table 28.1).

In Table 28.2 we can see the anatomical characteristics of our patients.

In Table 28.3, our patient Epworth sleepiness scale and polysomnographic results.

There were no differences in the results whether we performed or not multilevel surgery.

Furthermore, in 16 patients we have 2-year long-term results, and they remain stable in time (Fig. 28.8).

Table 28.1 Distribution of accompanying surgeries to Barbed Pharyngoplasty (BP)

Accompanying surgical techniques	% (Number of patients)
Tonsillectomy	86.76% (59)
Nasal surgery	45.59% (31)
Lingual tonsil coblation	5.88% (4)
Midline lingual coblation	17.65% (12)
Tongue base radiofrequency	2.94% (2)
Partial epiglottectomy	1.47% (1)

Table 28.2 Anatomical features for patients who underwent BP with or without multilevel surgery

Patient's features	All performed BRP $N = 68$	Non-multilevel BRP $N = 51$
Tonsil grade 0	8.82% (6)	3.92% (2)
Tonsil grade 1	19.12% (13)	16.18% (11)
Tonsil grade 2	23.53% (16)	16.18% (11)
Tonsil grade 3	45.59% (31)	38.24% (26)
Tonsil grade 4	2.94% (2)	1.96% (1)
MMI grade 1	4.41% (3)	1.96% (1)
MMI grade 2	47.06% (32)	38.24% (26)
MMI grade 3	41.18% (28)	39.22% (20)
MMI grade 4	7.35% (5)	7.84% (4)
Friedman Index grade 1	23.53% (16)	29.41% (15)
Friedman Index grade 2	54.41% (37)	49.02% (25)
Friedman Index grade 3	22.06% (15)	21.57% (11)
BMI	Mean 28.09 SD 3.97	Mean 28.42 SD 4.24
AGE	Mean 41.3 SD 11.65	Mean 40.75 SD 11.52

MMI Modified Mallampti Index, *BMI* body mass index
(): each group *n*
SD standard deviation

Table 28.3 Main sleep parameters before and after surgery for all performed BP and non-multilevel BP

	All performed BP pre $N = 68$	All performed BP post $N = 68$	*P* value	Non-multilevel BP pre $N = 51$	Non-multilevel BP post $N = 51$	*P* value
AHI	36.32 (24.42)	13.52 (14.22)	0.00	35.71 (23.77)	13.45 (14.53)	0.00
ODI	34.54 (22.4)	15.19 (16.36)	0.00	34 (21.42)	15.43 (17.55)	0.00
T 90	15.56 (20.76)	7.09 (10.82)	0.04	12.71 (18.56)	8.65 (11.97)	0.18
ESS	9.16 (5.25)	5 (2.89)	0.00	8.38 (4.96)	4.94 (2.91)	0.00

() standard deviation, *AHI* apnea-hypopnea index, *ODI* oxygen desaturation index, *T90* time spent with an oxygen saturation lower than 90%, *ESS* Epworth Sleepiness Scale

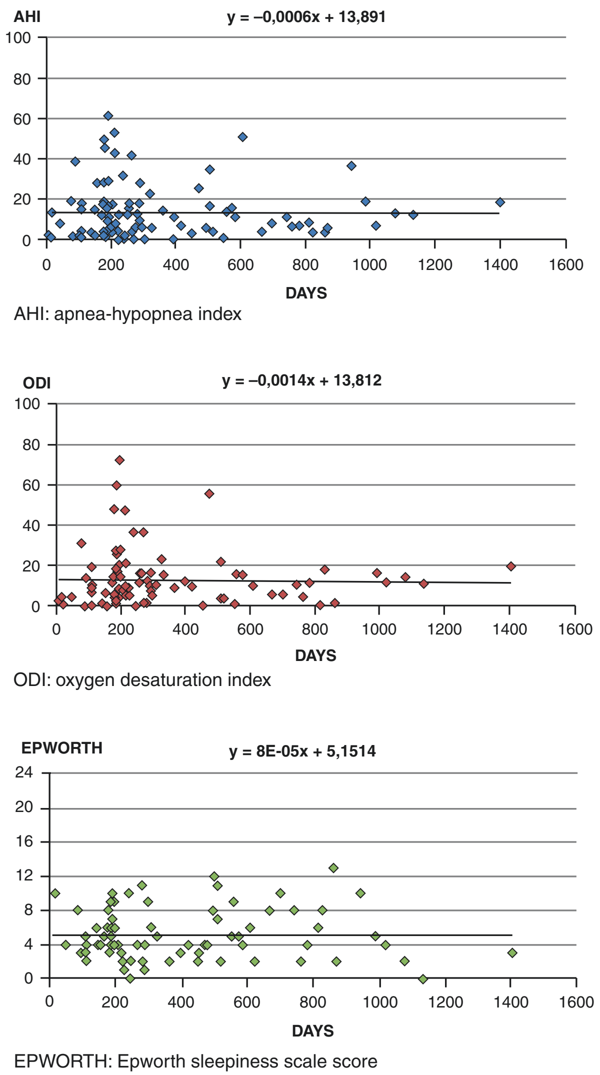

Fig. 28.8 Dispersion dots graphic of AHI, ODI, and ESS 2 years after the first control. The horizontal line indicates that the results remain stable

28.5 Indications

We are performing this technique in adult patients up to 70 years old, no matter the severity of OSA, who do not have indication or do not tolerate standard treatment with positive airway pressure (PAP).

Nasal surgery or multilevel surgery (tongue base radiofrequency midline glossectomy or partial epiglottectomy) can be performed at the same time. We prefer not to do lingual tonsillectomy in the same surgical time if the patient was not previously tonsillectomized due to the increased possibility of secondary bleeding.

28.6 Postoperative Care

The patient is extubated once the surgery is finished. They are admitted for one night and discharged from the hospital the next day.

We prescribe dexketoprofen 25 mg and tramadol 75 mg for the first 10 days when the pain is more intense and after those days or if the patient is intolerant to tramadol the patient reduces to dexketoprofen 25 mg/8 h. We explain the patient that could take paracetamol 1 g/8 h as rescue if needed.

For the velopharyngeal edema, we also recommend deflazacort (1 mg/kg/day) for 4–5 days.

Furthermore, we recommend prophylactic antibiotics, usually cefuroxime 500 mg for 10 days.

The first visit after the surgery is scheduled in 10–14 days, then 1 month and in 6 months a new sleep study is performed.

28.7 Complications

The most frequent complication is the partial extrusion of the suture. We do not know the percentage of extrusion but usually it occurs during the second postoperative week or later. If the extrusion bothers the patient creating discomfort, it can be cut, and this does not change the surgical result [7].

Sometimes the incision for the supratonsillar fat extraction is dehiscent, nevertheless it heals in second intention within a week or two (Fig. 28.9).

There is also risk of primary or secondary bleeding due to tonsillectomy.

Velopharyngeal incompetence is possible albeit rare and does not endure longer than the first three postoperative days.

In some patients, relaxation of the tension on one side may occur more than on the other resulting in an asymmetric the palate.

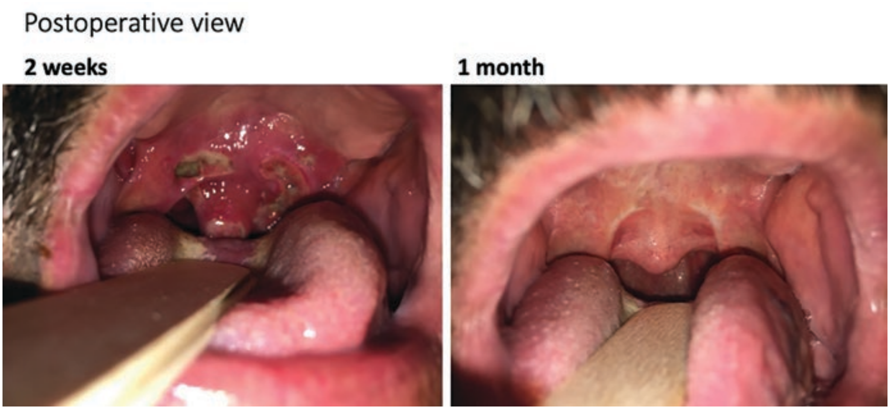

Fig. 28.9 Dehiscence of the fat closure and healed after 2 weeks

28.8 Discussion

Our pharyngoplasty technique is versatile and adapts to the patient anatomy and type of collapse observed in DISE. As we use long threads, we can perform many steps and loops in the LPW and soft palate that, according to the coaxial tubes' theory by Mantovani [2], allows to share the rigidity of the outer structures to the inner soft-tissue, reducing their collapsibility.

Nevertheless, it has some limitations. It takes longer operating time than the BRP, and the more stitches you have in the soft palate the higher the possibility of some extrusion. However, the extrusion if present, appears from the second postoperative week, when the scaring/healing of the wounds has already started. After the section of the extruded thread, the problem is resolved and the palate stays in position [7]. Despite performing the zig-zag suture to close the incision in the lateral palatal space after removing the supratonsilar fat, in some patients this incision does not close, but heals in second intention in a couple of weeks without need for further treatment.

The surgery has good short, middle, and long-term results. In our hands, and has proven to be the surgical technique with optimal results [8].

Acknowledgements To Ángel Gálvez Núñez for his invaluable help with the surgery drawings.

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29 Technical Update of Barbed Pharyngoplasty for Retropalatal Obstruction

Fatih Gul and Mehmet Ali Babademez

29.1 Introduction

Barbed pharyngoplasty (BP), a soft palate lifting technique, was first introduced by Vicini and his colleagues [1]. In this technique, soft tissues on both sides of the uvula are supported to the hard and fixed tissues on the laterals, separately. Most of the soft tissue burden is transferred to the horizontal structures. In some patients, midline soft tissues as well as redundant uvula may be flexible and collapsible under air pressure. In our modified technique, the soft palate is fixed to the lateral structures with a single continuous suture. We modified the classical technique because working within the midline of soft palate also produces larger effects on anteroposterior pharyngeal space.

29.2 The Mechanism of Vectorial Collapse and Obstruction

The surgeries of soft palate aim to facilitate static opening of lateral pharyngeal retropalatal space, advance the soft palate anteriorly, and reduce lateral wall compliance by altering lateral pharyngeal wall and soft palate at the level of velopharynx and oropharynx [2]. Considering the development of soft palate surgeries, it is desired to pull the soft palate into two vectorial directions, lateral and anteroposterior. Vectorial collapse or obstruction of retropharyngeal space based on drug-induced sleep endoscopy (DISE) indicates the choice of surgical technique (Fig. 29.1). We believe that modified barbed pharyngoplasty (MBP) satisfies the expectations of enlarging of both lateral and anteroposterior directions.

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_29

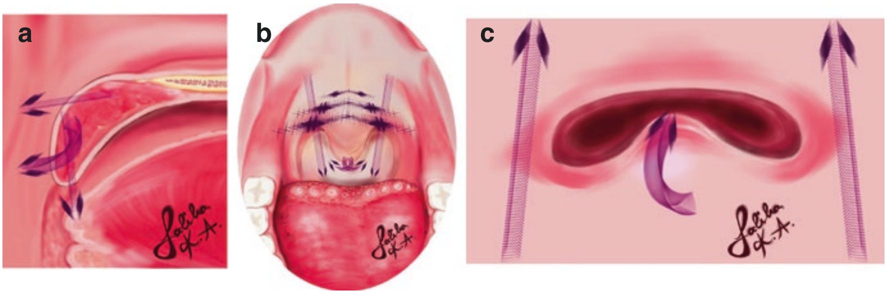

Fig. 29.1 Vectorial collapse or obstruction at the level of velum in sagittal (**a**), anterior (**b**), and horizontal view (**c**)

29.3 Why Barbed Pharyngoplasty?

Among the common currently applied soft palate surgeries, anterior palatoplasty (AP) technique is used to provide anteroposterior pharyngeal enlarging, while expansion sphincter pharyngoplasty (ESP) technique leads horizontal pharyngeal enlarging. Combining both techniques may provide maximum benefit in enlarging the posterior pharyngeal space in both lateral and anteroposterior planes [3]. The similar effect of these combined surgeries may be achieved alone with BP. In 2020, our department has conducted a study to compare the functional outcomes in patients who underwent ESP with AP versus BP only [3]. Success rates were 86.6% in the BP group and 84.9% in the ESP with AP group. The decrease in mean apnea-hypopnea (AHI) scores was determined as 31.9% in ESP with AP group and 28.5% in the BP group. Although no statistically significant difference was seen, BP technique may be preferred due to its less invasive and easy to learn nature.

29.4 Development of Modified Technique

After gaining experience in BP, we observed that in some cases where the uvula and its upper redundant soft tissue were elongated, the BP technique was insufficient to lift or tighten the midline of soft palate (posterior nasal spine-uvula line). To overcome this drawback, we updated the BP technique by using a single continuous suturing passing through the base of uvula. Thus, the need of partial uvulectomy was eliminated. In our department, we perform routinely MBP in patients with retropalatal collapse regardless of having elongated uvula or not.

29.5 Advantages of Modified Technique

MBP, a simple variant of BP, offers several advantages, as follows: The BP method requires two interventions to the soft palate by using one or two barbed sutures, whereas MBP requires only a single continuous suture to pull up the uvula and soft palate. Although BP is partially effective in maintaining anteroposterior oropharyngeal airway patency, its main effectiveness is in lateral oropharyngeal expansion. MBP is especially preferable in both lateral and anteroposterior directions. Multiple lateral sustaining sutures and then passing through base of uvula in modified technique provide more stable soft palate suspension than the classical technique. In summary, the more redundant and elongated midline soft tissue including the uvula, the greater the indication for MBP.

29.6 Our Experience: Modified Vs Classical Technique

In 2019, our department has conducted a study to compare the outcomes of BP and MBP with a minimum 6 months of follow-up [4]. Preoperative and postoperative Epworth Sleepiness Scale (ESS), snoring visual analogue scale (sVAS), and polysomnographic features were compared in 34 patients (17 in the BP group, 17 in the MBP group). Overall, there were no statistically significant differences between the groups in terms of all parameters. Although the number of participants was limited, the reductions were notable; ESS score reduction was 4.8 in BP and 5.5 in MBP, sVAS score reduction was 4 in BP and 6.2 in MBP, total AHI reduction was 22.5 in BP and 24.8 in MBP, supine AHI reduction was 26.8 in BP and 35.3 in MBP. The reason for the greater gain in supine AHI in the MBP group may be due to anterolateral expansion in the retropalatal area. However, further studies are required to support these outcomes. Moreover, we demonstrated that selecting a threshold of a 50% reduction in AHI and AHI less than 20 events/h, success rates were found 95% for MBP and 82% for BP. Given recent improvements in barbed threads and ongoing demand for minimally invasive procedures, we usually apply modified barbed suture technique for a soft palate surgery.

29.7 Preoperative Evaluation

Before the surgery, the sleep apnea surgeon must answer the critical question, *Can the patient get benefit from a soft palate surgery?* Per standard clinical practice at our department, sleep apnea surgeons perform DISE-recorded findings in a standardized fashion using the Velum-Oropharynx-Tongue Base-Epiglottis (VOTE) scoring system [5]. Configuration of anteroposterior, lateral, and concentric obstruction is noted for structures with a degree of obstruction greater than zero. After the obstruction areas are determined, a single-stage or multi-stage surgery decision is made.

29.8 Surgical Technique

The BP technique has been mentioned in detail in the previous sections. Therefore, the main steps will be mentioned and the differences between MBP and BP will be emphasized in this section.

All procedures were conducted under general anesthesia. Once bilateral tonsillectomy is performed, palatopharyngeal muscle is partially released to lift posterior pillar. We usually apply 23-G barbed polydioxanone (PDO) thread. Submucosal lidocaine with adrenaline injection is performed to control bleeding and soft palate is marked for suture placement. First needle insertion and final extraction points are marked on the periosteum of posterior nasal spine. Other mark reference points are pterygoid hamulus, pterygomandibular raphe, and base of uvula (Fig. 29.2). Since the mucosal entry and exit points of the thread are passed from the same point, there is no need for any mucosal excision. One barbed PDO thread is placed on the center point (periosteum of posterior nasal spine) and then continued along the planned marking lines. It is maneuvered within the muscular plane, guided by the force on the surgeon's hand. Once the pterygomandibular raphe is contacted, the needle turned 360-degree angle to palatopharyngeal muscle. It is stitched three times to achieve a firm fixing. Then, the thread is passed horizontally through the base of uvula to transfer the tension from midline to lateral fixed structures. The same procedure is performed for opposite side of the soft palate. The last maneuver of the MBP is that pulling the needle out from the insertion point. After all the barbed suture is positioned in the soft palate, the surgeon holds the needle in one hand and pushed the soft palate in the opposite direction with the other hand to fully engage the thread and lift the soft palate including midline. Distal and proximal part of thread are locked down at the center point (posterior nasal spine). Finally, the soft palate is shortened, tightened, and pulled forward to enlarge posterior pharyngeal space in both lateral and anteroposterior directions. The main surgical steps of MBP are illustrated (Fig. 29.3).

Fig. 29.2 Marking the reference points of the needle insertion and extraction

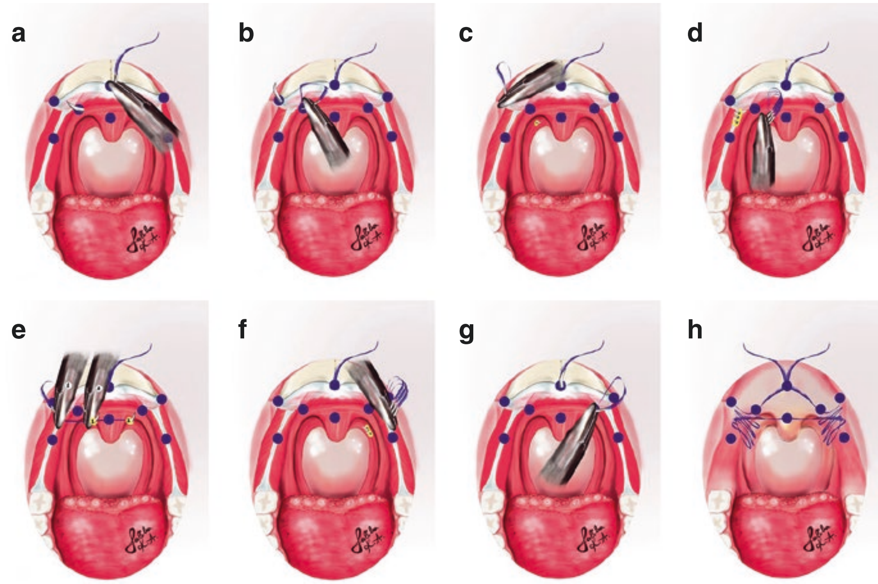

Fig. 29.3 (**a**) Suturing process starts from center point (periosteum of posterior nasal spine). (**b**) The thread is passed laterally within the musculature. (**c**) The thread is passed through periosteum of hamulus of medial pterygoid plate. (**d**) The thread is passed three times between released palatopharyngeus muscle and pterygomandibular raphe. (**e**) The thread is passed horizontally through base of uvula (continuous suturing with a single thread). (**f**) Same procedure is conducted on the opposite side. (**g**) Last suturing is finalized at the first suturing site. (**h**) The stitches are locked at the center point

The surgical steps of MBP are commonly like BP excluding one major step: to maintain continuous suturing, a suture is passed horizontally through the base of uvula from one side tonsillectomy bed to opposite side tonsillectomy bed. Elongated uvula and redundant midline soft tissues are fixed to the stabilized soft palate with this maneuver. So, anteroposterior pharyngeal space is enlarged.

29.9 Modified Barbed Pharyngoplasty in Multilevel Surgery

Determining the anatomical and physiological site of obstruction is crucial for matching a patient to the appropriate surgical intervention. It is known that a patient with obstructive sleep apnea has mostly multilevel obstruction or collapse. In DISE examination, retropalatal collapse and tongue base obstruction are the most common sites of obstruction or collapse [6]. In our department, transoral robotic surgery is used to perform lingual tonsillectomy and tongue base reduction as a part of multilevel surgery. We have experienced that the probability of being oropharyngeal synechiae increases in cases where palatine tonsillectomy and lingual tonsillectomy are performed simultaneously. However, this is not valid in cases where palatine tonsillectomy and tongue base reduction are performed together. Although rare, oropharyngeal synechia have been reported in patients with previous tonsillectomy or no history of tonsillectomy [7]. The key point is that the surgical area on the base of the tongue and the tonsillectomy bed should not encounter with each other. While this possibility is higher in lingual tonsillectomy, it is negligible in tongue base reduction because of the distance of surgical sites. In addition, care should be taken to avoid excessive cauterization and being a systemic disease that promotes keloid development of the patient.

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30 Barbed Suspension Pharyngoplasty (BSP)

Marco Barbieri, Davide Mocellin, Francesco Missale, Fabiola Incandela, and Marco Fragale

30.1 Introduction and Indications to the Surgical Technique

Since the introduction of non-resective pharyngoplasty techniques, as the expansion sphincter pharyngoplasty [1], a decrease in surgical complications and improvement of success has been observed [2].

Furthermore, the introduction of barbed sutures in pharyngeal surgery by Mantovani [3] in his "roman blinds" technique and the increasing use of this type of sutures by many surgeons, led to a development of different technique as the barbed reposition pharyngoplasty [4] and the barbed expansion pharyngoplasty [5]. Indeed, barbed threads have a peculiar and innovative structure that allows the absence of knots and the unidirectional passage in the soft tissues during suture. Care has to be taken and traction of the wire must be gentle. Indeed, if traction is too strong, it is possible to generate a curling of the mucosa with poor cosmetic and functional outcomes. Furthermore, one must bear in mind that when the barbed thread is pulled out it is not possible to come back with the stitch without causing tissue injury because of the microscopical features of the wire itself.

It is available with the needle only on one side of the thread or with a needle from each side and a transition zone in the middle. This type of suture seems to reduce

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_30

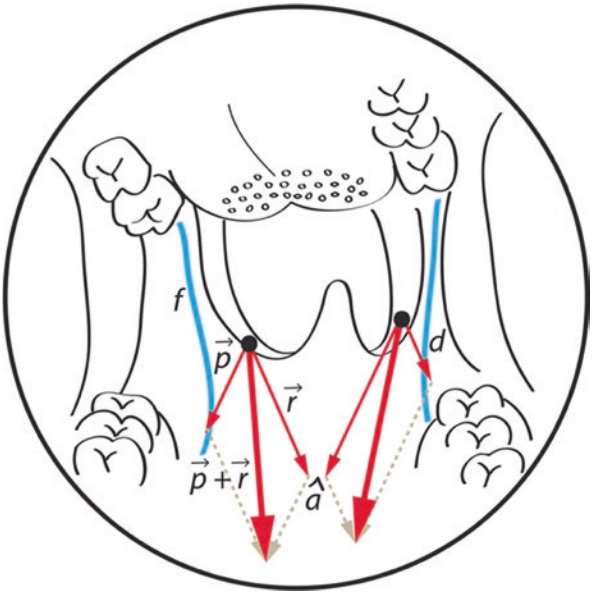

Fig. 30.1 The figure, depicted from the surgical view, shows the main force vectors, *p* and *r*, and their sum (*p* + *r*). *a*, posterior nasal spine; *d*, right pterygomandibular raphe; *f*, left pterygomandibular raphe; blue lines represent the pterygomandibular raphes

invasiveness and operating times without the need of making knots inside the oral cavity and oropharynx [2].

The Barbed Suspension Pharyngoplasty (BSP) is a quite young surgical technique, first described in 2019 by Barbieri et al. [6]. Inspired by surgical technique described by Vicini [4] and the so-called barbed reposition pharyngoplasty, with the BSP we introduced some surgical steps to increase the latero-lateral tension and to achieve the anteroposterior suspension of the soft palate through tension vectors using the posterior nasal spine and the pterygomandibular raphe as points of fixation. In BSP technique, the suture's passage from these two points of fixation leads to the anterior displacement of the soft palate as results by the sum of the main vector forces (as showed in Fig. 30.1).

The multiple passages of the suture through the soft tissues determine the stiffness of the soft palate that can be attributed to the postoperative cicatricial fibrosis, thereby reducing its collapsibility which is one of the main causes of obstructive apnea in these patients.

Before starting the surgery, it can be useful to obtain the following linear measures under direct vision by the surgeon:

1. Uvula length: the distance between the posterior nasal spine to the apex of the uvula
2. Arch length: the distance between the palatal arch and the posterior end of the hard palate
3. Lateral width: the distance from both posterior pillars measured on an axial plane at the level of the apex of the uvula
4. Anteroposterior width: distance from the posterior pharyngeal wall to the soft palate at the level of the uvula

30.1.1 Surgical Step

The surgical steps are follows as schematically illustrated in Figs. 30.2 and 30.3. The drawings show the technique performed on the right side. Analogue and symmetric procedure must be performed on the left side. As can be clearly seen, the perspective is from the surgeon point of view.

After the induction of general anesthesia, hyperextension of the head of patient is of fundamental importance to the optimal oropharyngeal exposure that is achieved by a Boyle–Davis mouth gag. It is crucial that the surgeon could clearly see the entire soft palate and the tonsillar beds.

– Firstly, the Boyle–Davis mouth gag is kept open for the correct exposure of the surgical field. It can be used a surgical ruler with 1 mm as the unit of measure to collect the abovementioned oropharyngeal distance (Fig. 30.4). The measure-

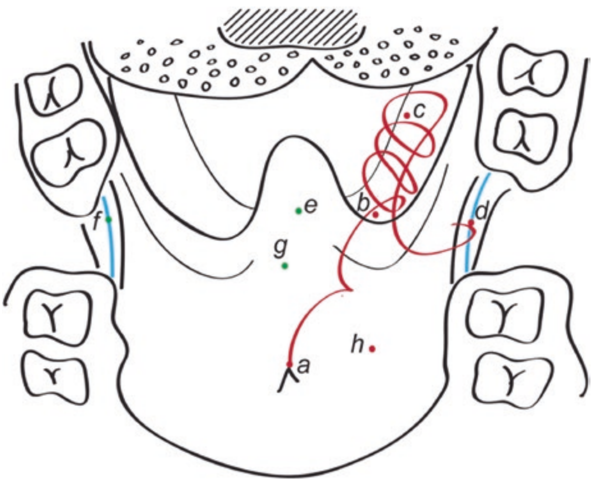

Fig. 30.2 Here is shown the schematic surgical drawing illustrating the planning of suture route (red line) on the right side starting at the level of posterior nasal spine until reaching the ipsilateral pterygomandibular raphe. *a*, posterior nasal spine; *b*, apex of tonsillectomy bed; c, palatopharyngeal muscle; *d*, right pterygomandibular raphe; *e*, base of the uvula; *f*, left pterygomandibular raphe; *blue lines*, pterygomandibular raphes

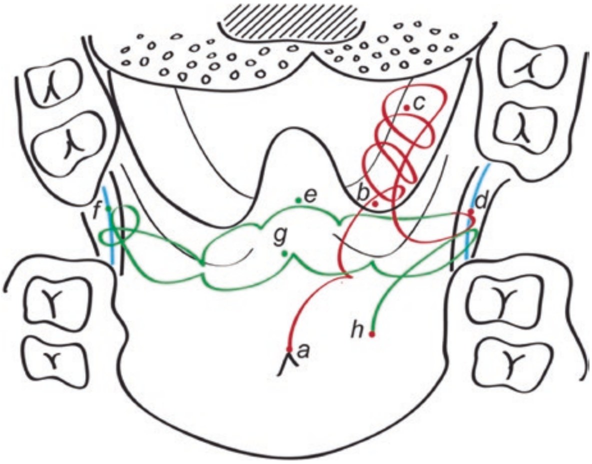

Fig. 30.3 The figure illustrates the addition of suture route in the soft palate running from the ipsilateral pterygomandibular raphe to the contralateral one toward the base of uvulae (green line). Then, it can be seen the suture route running back on the right side. *a*, posterior nasal spine; *b*, apex of tonsillectomy bed; c, palatopharyngeal muscle; *d*, right pterygomandibular raphe; *e*, base of the uvula; *f*, left pterygomandibular raphe; *blue lines*, pterygomandibular raphes

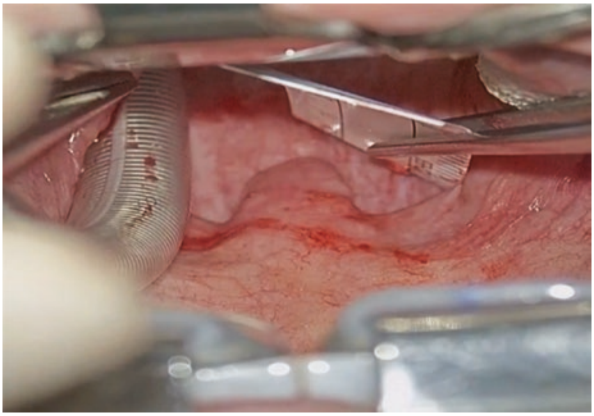

Fig. 30.4 It can be seen the oropharyngeal exposition with Boyle–Davis mouth gag, the endotracheal tube on the left, and the surgical forceps holding the ruler. Here the anteroposterior width is measured

ments thus obtained in the preoperative and postoperative setting could be compared to evaluate the augmentation of the oropharyngeal inlet.

– We could face with two types of scenarios: patients underwent or not a previous tonsillectomy. If patients had already been subjected to a previous tonsillectomy, we need to demucosized the tonsillar lodge to expose the palatoglossus and palatopharyngeal muscle. If patients need a tonsillectomy, this surgical step is performed according to surgeon preference.

The absence of palatine tonsils or their surgical excision before starting the BSP is necessary for two main reasons: the first one is the removal of a structure that can often be involved in the genesis of the oropharyngeal obstruction. The second reason is that performing the tonsillectomy allows to expose the palatopharyngeal muscle that is the surgical target to execute this surgical technique correctly; in fact, the suture encompasses this anatomical structure to obtain a posterolateral vector of traction resulting from fixation at the level of ipsilateral pterygomandibular raphe and the posterior nasal spine.

– Using bidirectional barbed sutures PDO 2.0, the first stitch is from the midline (Fig. 30.5), where the needle embraces the posterior nasal spine (Fig. 30.6). The wire, usually, is then conducted in this direction in two passages, reintroducing the needle in close proximity to the previous exit point (Fig. 30.7).
– From the prospective of surgeon, the suture proceeds in an anterolateral fashion towards the apex of tonsillar bed (Fig. 30.8).
– After that, multiple stitches (from 2 to 4 passages) are placed around the upper portion of palatopharyngeal muscle, anchoring it to the anterior pillar maintaining the suture in a submucosal plane (Figs. 30.9 and 30.10).
– A suspension stitch is then made by passing the needle around and lateral to the ipsilateral pterygomandibular raphe doing gentle traction to avoid injuring of palatopharyngeal muscle and the mucosa (Figs. 30.11 and 30.12).

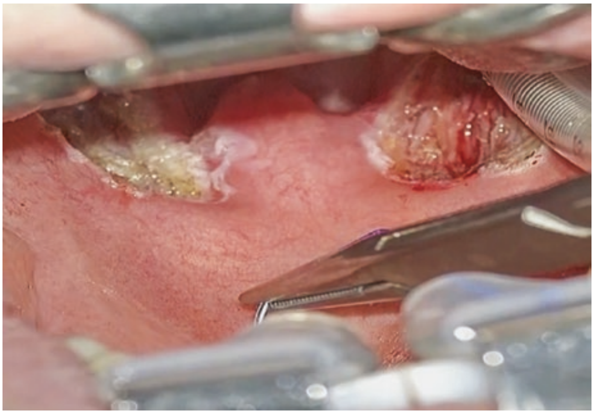

Fig. 30.5 In the figure is shown the exposition of oropharynx and the first insertion of the needle in the soft palate at the level of posterior nasal spine after the identification of the anatomical landmarks

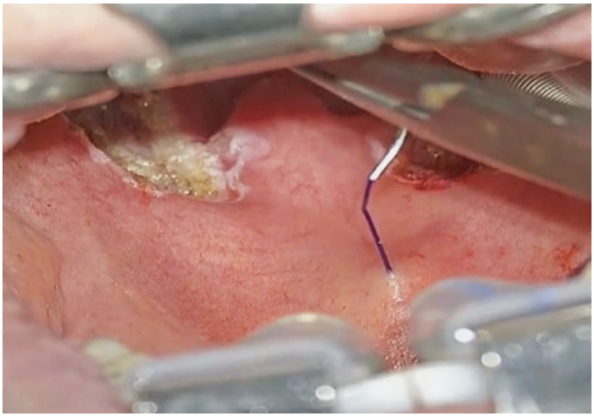

Fig. 30.6 The figure shows the first point of exit of the needle in the soft palate after surrounding the posterior nasal spine

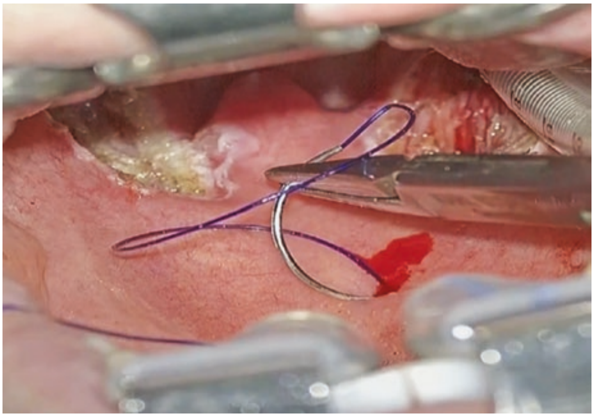

Fig. 30.7 The figure shows the needle during its insertion close to the previous point of exit

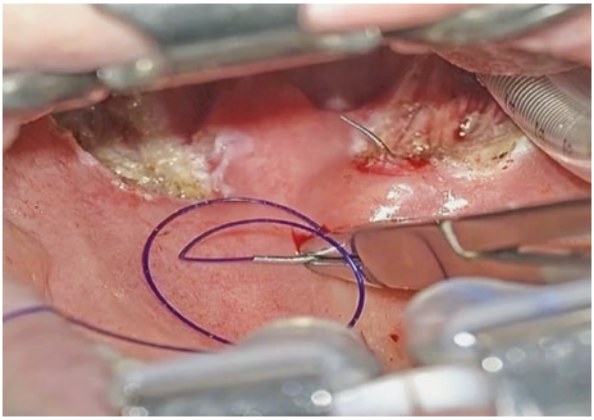

Fig. 30.8 The figure depicts the needle coming out at the superior apex of the right tonsillectomy bed

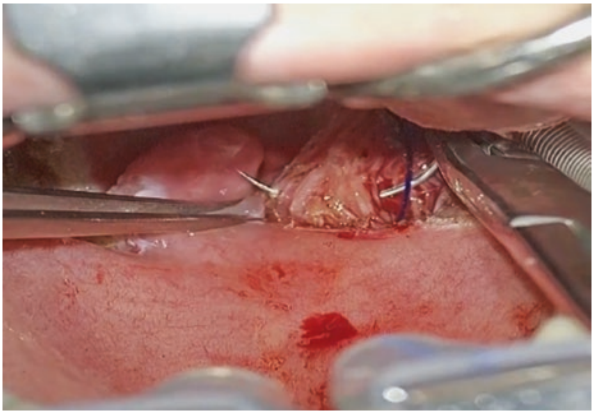

Fig. 30.9 The figure shows the first passage of the needle in the upper portion of palatopharyngeal muscle. Here the needle coming out in a submucosal plane

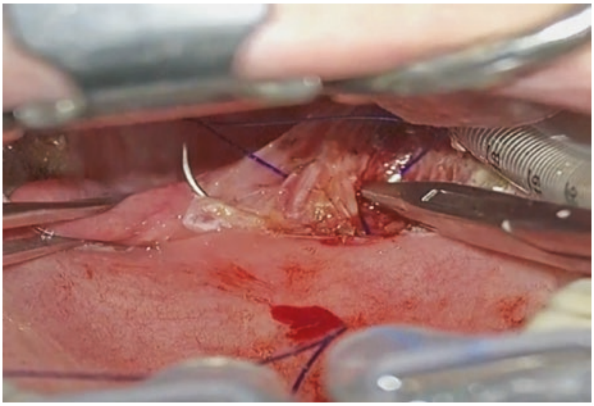

Fig. 30.10 Here it can be seen the second passage of the needle around the upper portion of the palatopharyngeal muscle. Usually, it is suggested to place multiple stitches (from 2 to 4 passages) in this surgical phase

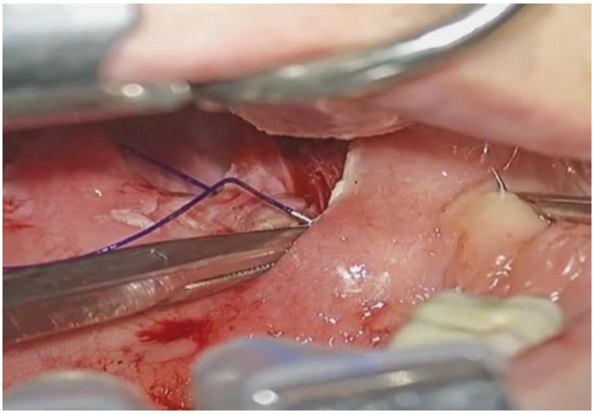

Fig. 30.11 After the multiple sutures of palatopharyngeal muscle are performed, it is mandatory to anchor it to pterygomandibular raphe. The figure shows the tip of the needle emerging lateral to the abovementioned structure

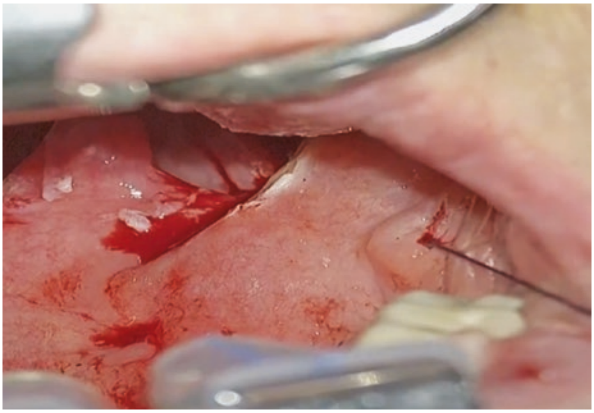

Fig. 30.12 In the figure it can be seen the effect by the traction of the wire that is performed without knots. The palatopharyngeal muscle is displaced anteriorly and laterally with an evident incrementation of the retrovelar space

- Further stitches are placed in the palatal muscles through the base of the uvula and the soft palate (Fig. 30.13). The aim of this step is to create a grid inside the soft palate to ensuring its stiffening determined by scarring process during post-operative healing.
- The suture is carried out until reaching the contralateral pterygomandibular raphe.
- Indeed, this is another important point of fixation for our suture (Fig. 30.14).
- Then, the needle going back in the soft palate through the midline to the ipsilateral pterygomandibular raphe (Figs. 30.15 and 30.16), and finally the suture is cut (Fig. 30.17).
- The surgical steps are then repeated from the other side with the contralateral needle of the same bidirectional barbed thread. The starting point is the posterior nasal spine yet again (Fig. 30.18).

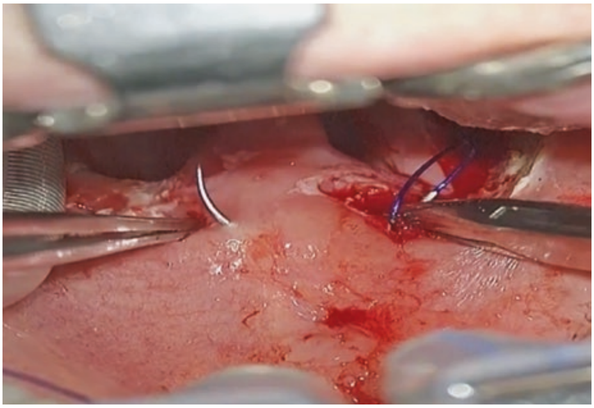

Fig. 30.13 The figure depicts the further passage of the needle in the soft palate, near the base of uvula, in a horizontal contralateral direction (here towards the left side)

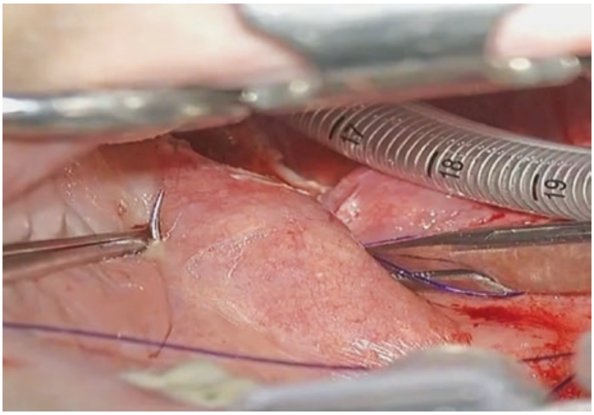

Fig. 30.14 The figure clearly shows the tip of the needle emerging lateral to the left pterygomandibular raphe

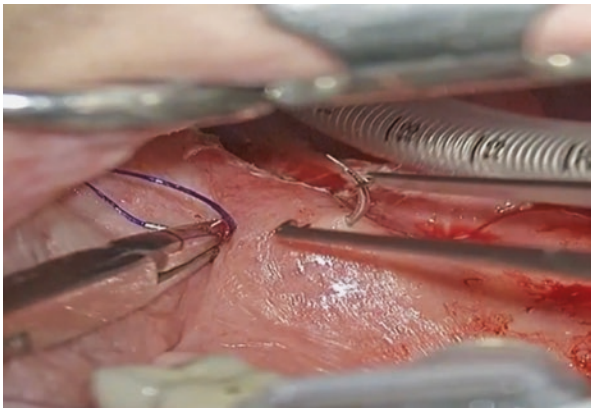

Fig. 30.15 In this figure it can be seen the needle going back towards the midline. The suture proceeds until reaching again the right pterygomandibular raphe

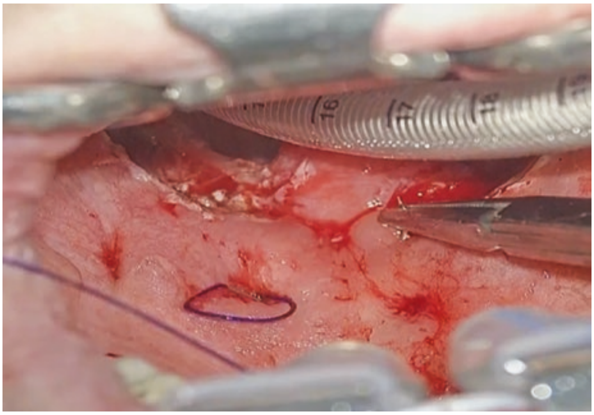

Fig. 30.16 In this figure is shown the passage of the needle in the soft palate coming back through the midline. Suturing in the soft palate, it is mandatory to reinsert the needle in very close proximity to the previous point of exit

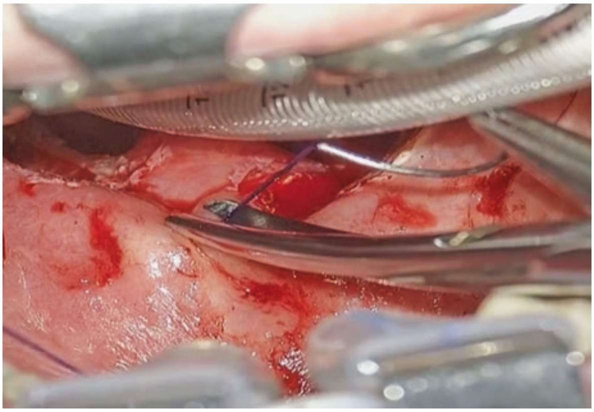

Fig. 30.17 The figure depicts the cut of the needle with a pair of surgical scissors at the end of the suture. The right side of the suture is now completed

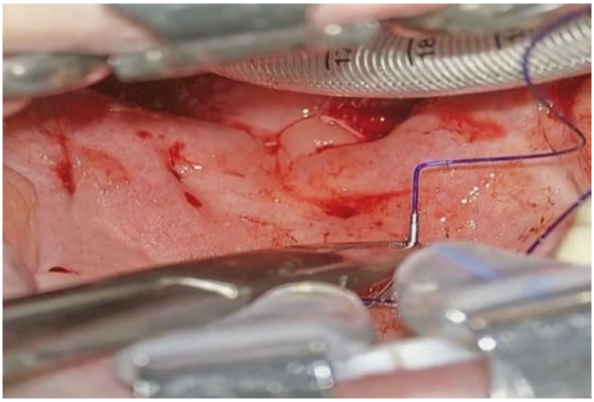

Fig. 30.18 The figure shows the starting point of the suture on the other side (left side in this example) beginning from the posterior nasal spine yet again

- Similarly, the suture is led towards the tonsillectomy bed where multiple stitches are given around the palatopharyngeal muscle (Fig. 30.19) anchoring it to pterygomandibular raphe (Figs. 30.20 and 30.21).
- The suture then reaches the contralateral pterygomandibular raphe through the soft palate (Figs. 30.22 and 30.23) and consequently the needle is cut. The multiple passage of the suture in both direction inside the soft palate is aimed to create a submucosal net that will allow the development of palate stiffening during postoperative healing process.
- When performing this surgical technique, the uvula is not routinely resected. However, if the uvula is too long it is generally trimmed. This is necessary to avoid poor functional outcome, because a long and enlarged uvula could cause a postoperative snoring due to its vibration, also after that healing process is completed.
- At the end of the BSP procedure it can be appreciated the increasing distance between lateral oropharyngeal walls and how much the soft palate looks anteriorized (Fig. 30.24).
- At very end of the surgical step from both sides, further measures are always taken to compare them with that acquired in the preoperative phase (Fig. 30.25).

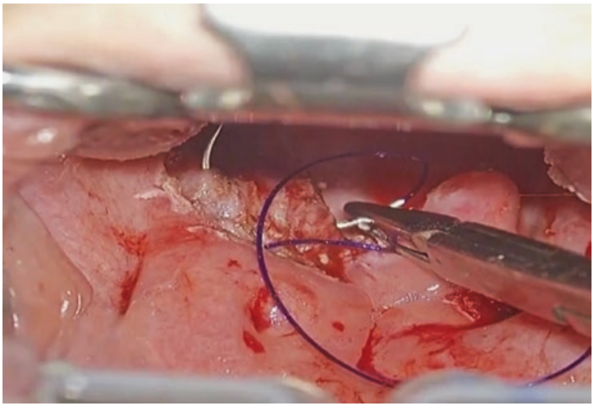

Fig. 30.19 The left tonsillectomy bed is reached. In the figure it can be seen one of the multiple stitches encompassing the palatopharyngeal muscle

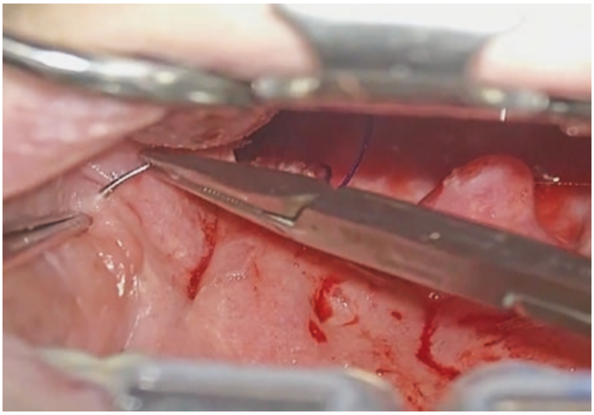

Fig. 30.20 The picture shows the needle coming out lateral to the left pterygomandibular raphe to anchor the suture and to allow the anterolateral expansion of the palatopharyngeal muscle

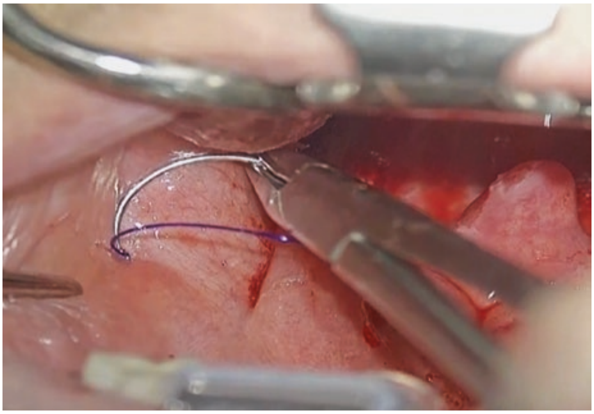

Fig. 30.21 One of the main fixations point of the suture is the pterygomandibular raphe and it is mandatory to surround this structure with the wire. The figure depicts the reinsertion of the needle lateral to the left pterygomandibular raphe

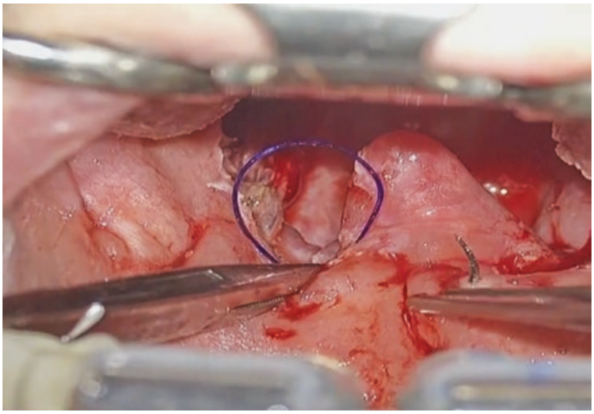

Fig. 30.22 The figure shows the suture proceeding to the right side and the needle coming out from the soft palate mucosa in the midline near to the base of uvula

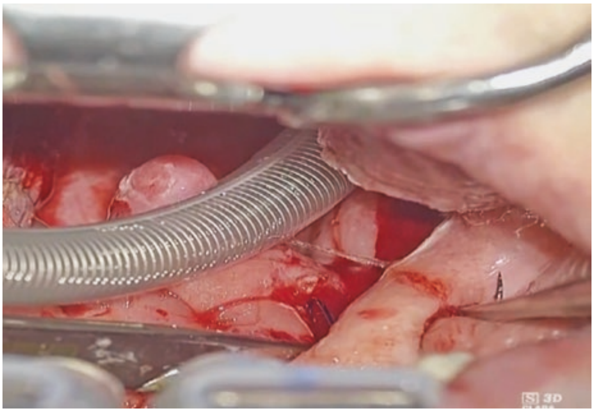

Fig. 30.23 The contralateral side is reached and it can be seen in this figure the needle coming out lateral to the right pterygomandibular raphe

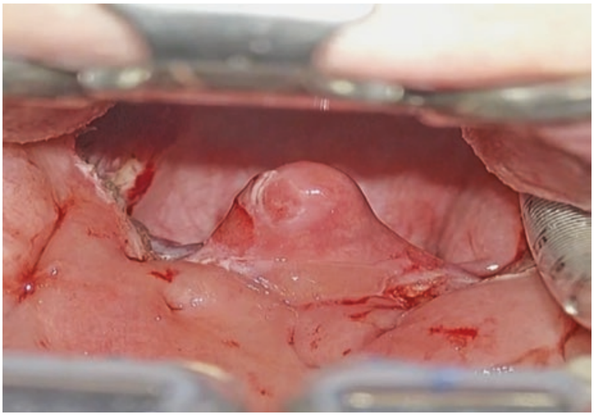

Fig. 30.24 The figure shows the final result after the execution of the surgical technique on both sides

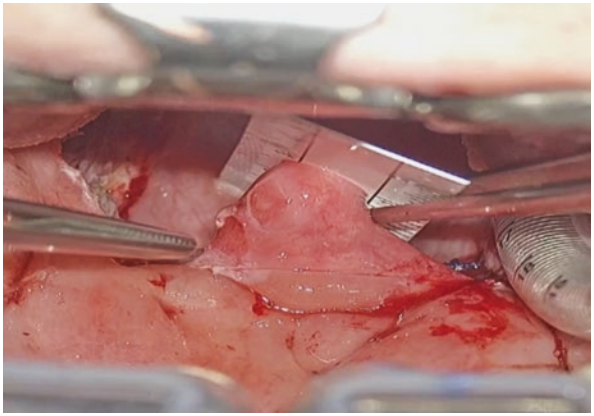

Fig. 30.25 As shown in the figure, the measurement of the anteroposterior width, as well as the other measures that are described in this chapter, can be obtained with a surgical ruler to better compare preoperative and postoperative values

The main indication for BSP is for treatment of OSAS patients with evidence of a collapse of the soft palate. The collapse at the oropharyngeal level has been already classified by Vicini et al. [7]. This classification can be used both in office setting and during Drug Induced Sleep Endoscopy (DISE).

It goes without saying the relevance of evaluation of palatal collapse especially during DISE performed before the surgical treatment. Nowadays, DISE is the well-known cornerstone of the decision-making process in the workup of patient affected by obstructive sleep disorder and its importance and the correct execution is well defined by guidelines [8].

It can be distinguished the grade and the pattern of oropharyngeal collapse. The former must be described as a percentage value: grade 1 is defined as 0–25% collapse, grade 2 as 25–50%, grade 3 as 50–75%, and grade 4 as 75–100%. Instead, the different patterns of collapse are described as follows: transversal, if the collapse is predominantly given by movement of the lateral pharyngeal walls; anterior-posterior, if an anterior wall collapse is visualized against the posterior pharyngeal wall; circular, if the collapse detected is a combination of the two patterns previously described [7].

In a paper recently published by Missale and colleagues, the outcome analysis has been highlighted that incrementation of the anteroposterior width (measured as distance from the posterior pharyngeal wall to the soft palate at the level of the uvula) seems to be one of the best predictors of success performing non-resective pharyngoplasty, among which the BSP [9]. This may suggest that BSP can be extremely useful to treat patient with anterior-posterior and circular pattern of oropharyngeal collapse.

The barbed suspension pharyngoplasty technique can be useful in patients presenting a severe annoying snoring when there is an evidence of its palatal origin. This aspect can be highlighted during the endoscopic evaluation of the upper airways where a remarkable and vibrating redundant mucosa at the level of uvula and soft palate can be seen. Usually, it is evident only during the sleep endoscopy but sometimes it can be seen also performing awake fiberoptic nasopharyngeal endoscopy. The utility of soft palate surgery on heavy snorers has been already underlined in literature by Salamanca et al. [10] where they observed a reduction of the mean score in the snoring visual analogic scale from 9.2 to 2.9, and, based on bed partners' opinions, they obtained a consistent reduction of snoring after the healing process (i.e., palatal fibrosis, reduction of edema).

Anyway, it is always crucial the careful selection of patient that are candidate to this type of surgical indication to ensure the right cost-effective relation and to improve the quality of life of these patients.

The value of AHI obtained by a polysomnographic analysis has a pivotal role regarding the indication to perform or not a surgical treatment in the obstructive sleep disorder. When facing to patients with high level of AHI, surgery shouldn't be always excluded because there could be multiple sites of obstruction. Especially when patients refuse cPAP therapy or they are not compliant to its use, it can be suggested to perform DISE to better evaluate the upper airways and give indication to other strategy of treatment, either surgical on nose, oropharynx, hypopharynx, and epiglottis or not surgical as oral appliance therapy or positional therapy.

Undoubtedly, it is well known that cPAP therapy allows a significant reduction of AHI and excessive sleepiness assessed by ESS score, as well as the improvement of diurnal blood pressure and in sleep-related quality of life questionnaire [11], so that is considered the gold standard for this type of patients. However, there are some pitfalls regarding the patient's compliance to cPAP therapy. First of all, it is a symptomatic treatment: the efficacy in maintaining the value of AHI in a physiological range is present only when using the device. On the other side, surgical procedure allows to achieve stable although not permanent results. In addition to this, a lot of patients do not tolerate the cPAP devices because of loudness, facial discomfort, dryness of the nose and mouth, and skin irritation.

It deserves to remember patients that had been previously underwent to a surgical treatment for OSAS. The most recent technique including non-resective pharyngoplasty have certainly improved the clinical result with low rate of postoperative complication. But for decades surgical technique such as laser-assisted uvulopalatoplasty (LAUP) has been used as treatment option for snoring and obstructive sleep apnea. The use of this technique led to an overall rate of complication of 26% with a high failure rate in reduction of AHI value [12]. In the patients underwent LAUP, the BSP could play a role to reduce the circular cicatricial stenosis present at the oropharyngeal level thanks to the anteriorization of the soft palate.

There are also some contraindications to BSP. Certainly, one of these is the presence of a body mass index over 35 because the surgical treatment will lead to an unsatisfactory rate of success. The BMI, the increase of weight, and the neck circumference are among the main patients' clinical features and their role in the genesis of the obstructive sleep disorder was well established in these past years [13]. However, every single patient has to be evaluated and sometimes if it is present an overweight condition without obesity could be indicated to perform surgery. Moreover, it is of crucial relevance to insist on patient to reduce his weight because obesity and weight gain increased cardiovascular and stroke risk, incidence of diabetes mellitus, psychiatric disturbance like depression and other systemic comorbidities.

The last condition that represents a contraindication to BSP is the presence of craniofacial abnormalities with particular regard to retrognathia where mandibular advancement devices (MAD) and maxillofacial surgical procedures are the most adequate.

30.2 Results and Conclusions

The correct execution of the BSP technique does not always ensure the completely reduction of apneas and hypopneas in OSAS patients. In fact, the increase of oropharyngeal inlet and the incrementation of retrovelar palate space sometimes are not enough to reach physiological range of the AHI value. Noteworthy are the criteria established by Montevecchi et al. [14] to evaluate the outcome of patients underwent a pharyngoplasty procedure with PSG performed 6 months after surgery.

They consider outcome (based on AHI and ESS score values) as following:

– Cured: AHI <5 and ESS <10 and reduction >50%
– Success: AHI <20 and ESS <10 and reduction >50%
– Failure: AHI >20 and any ESS value and reduction <50%

The abovementioned criteria shows that the surgical success does not necessarily mean an AHI value in a physiological range (between 0 and 5). Indeed, even if the surgical treatment is conducted in the right way there are a lot of other clinical variables involved as well as patients' personal features.

The worst situation for the surgeons is to face with the failure of his surgical technique. In patients with a residual AHI > 20 or a high ESS value should be suggested the use of cPAP therapy to achieve a satisfactory value of these parameters.

Obviously, some factors above all the increasing of bodyweight leads to a neutralization of the surgical correction created with the BSP, so that in the long term the initial benefit of the surgery can be lost.

In our surgical series [6] we retrospectively analyzed 42 patients, 20 of them underwent to BSP. Mild (AHI 5–15), moderate (AHI 15–30), and severe (AHI > 30)

OSAS groups are identified through a preoperative PSG, and respectively five, eight, and seven patients were classified in each category. The postoperative PSG showed a 100% success rate with eight patients presenting a normal value of AHI (0–5) and twelve patients showing a mild OSAS. In the patients' groups treated with BSP the median score of preoperative ESS was 9 while in the postoperative setting showed a strong improvement with a median score of 0. We observed that patients underwent BSP showed a statistically significant reduction of median value of ESS, AHI, ODI, and t90 ($p < 0.001$).

In our series, neither early nor late complications were detected in the BSP group. Every patient of our series treated with the BSP technique complains odynophagia, especially that group with concurrent tonsillectomy. Despite this, they begin to eat semisolid diet in the first postoperative day, without need to routine prescription of oral corticosteroid to control edema and pain. The literature data reveal that barbed pharyngoplasty techniques are not burdened by intraoperative and postoperative major complications [15]. Unlikely, previous surgical technique as uvulopalatopharyngoplasty (UPPP) may, sometimes, develop complications of complications among which infections, hemorrhages, nasopharyngeal stenosis, nasopharyngeal reflux, and rhinolalia [16]. On the contrary in our clinical series [6] we never assisted to similar surgical complications. Occasionally (about 10% of cases), we assisted to a partial thread extrusion during the late postoperative office examination: this occurrence is caused by the intrinsic properties of the barbed suture taking several months to dissolve itself. The wire visible during ENT examination can be simply cut with a surgical scissor without necessity to perform local anesthesia.

It is not uncommon to have more than one obstructive upper airways site in the genesis of OSAS. From this evidence born the concept of multilevel surgery in the management of OSA patients. The BSP can be safely associated to other surgical technique in a single time surgery.

For example, the oropharyngeal site of obstruction can be associated to nasal septum deviation or turbinate hypertrophy. The purpose and the role of surgery on this anatomical district is the reduction of nasal resistances to improve the subjective symptoms of breathing and the quality of sleep of the patients. In our series [6] a multilevel surgical procedure with nasal surgery was chosen for 17 patients (85%) between them treated with BSP, by performing turbinoplasty in 7 (35%) and both septoplasty and turbinoplasty in 10 (50%).

Nowadays, the literature stated that the nose surgery alone for treatment of OSAS patients shows no efficacy but that may play a role and must be consider as a part of the multilevel OSA surgery [17].

A more important role of the surgery in multilevel procedure is the necessity to treat the primary collapse of the epiglottis. This can be clearly seen during DISE and if occurs it can be safely treated in a single time surgery in addition to BSP.

Different surgical technique of epiglottoplasty can be found in the literature. Certainly, noteworthy are the transoral glossoepiglottopexy described by Roustan and colleagues [18] and the so-called "epiglottis stiffening operation" described by Salamanca et al. [19].

In conclusion, the Barbed Suspension Pharyngoplasty is a reliable technique that showed good outcomes as well as a good compliance by patients and it can be safely and effectively performed either alone as single surgical intervention or as a part of a multilevel OSA surgery.

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A Personalized and Eclectic Use of Barbed Suture to Address Palate Abnormalities in Sleep Apnea Patients

31

Andrea Marzetti, Caterina Tripodi, and Ingrid Raponi

31.1 Introduction

Over the past 12 years, palatal surgical techniques for snoring and Obstructive Sleep Apnea Hypopnea Syndrome (OSAHS) correction have evolved from the classical uvulo-palato-pharyngo-plasty (UPPP) [1] to less invasive techniques aiming at enlarging the velopharyngeal lumen [2–5]. Since the publication of Kenny Pang's anterior palatoplasty and the introduction of barbed sutures in the Italian OSAHS group (2010) [4, 6–10], the so-called "snore surgery" has undergone an incredible technological and conceptual evolution. At the same time the Drug Induced Sleep (sedation) Endoscopy (DISE) [11] gradually became the keystone in the diagnosis, therapeutic and surgical planning of OSAHS patients. Over the last 10 years we have applied to selected patients all the proposed surgical techniques. In doing so, we have identified from each of these techniques a concept responsible for an evolutionary surgical process (Fig. 31.1). Therefore, from now on we will refer to "**evolutionary concepts**" as shown in Fig. 31.1. Basically, by observing the obstructive elements responsible for the different types of palatopharyngeal collapse, we were able to apply the most appropriate surgical technique in order to obtain the expected outcome (Fig. 31.1).

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*, https://doi.org/10.1007/978-3-030-96169-5_31

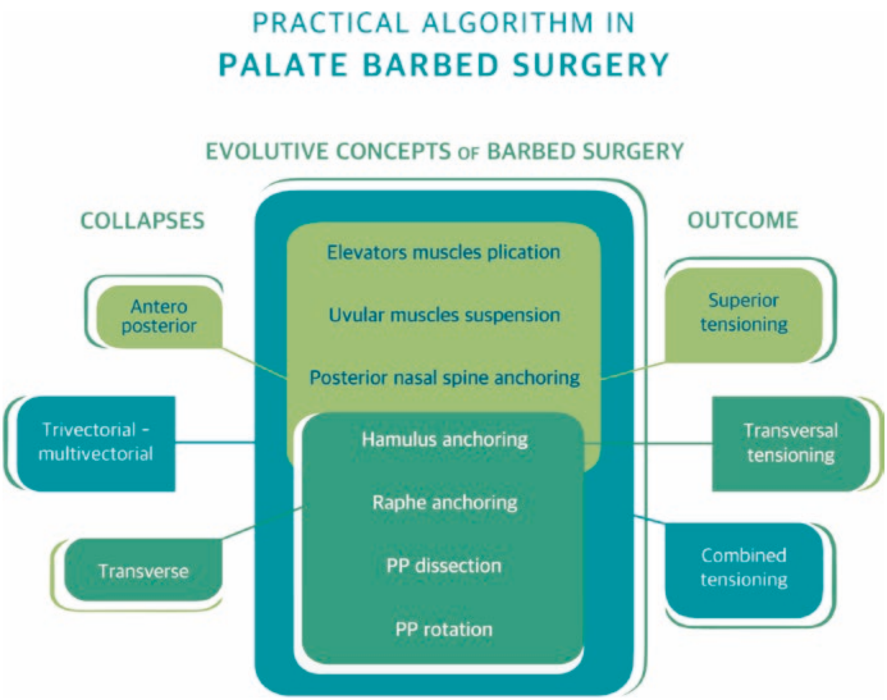

Fig. 31.1 Evolutive concepts in palate barbed surgery

In our concept of "eclectic barbed surgery," the surgeon is familiar with evolutionary concepts and chooses the most useful elements to handle each case, tailoring the operation to the patient and his specific problem. Similarly, once the evolutionary concepts are clear, any surgical approach can also be modified using access strategies different from those originally imagined (Fig. 31.1). In this chapter we will try to illustrate few examples (which we will call "*variants*") of eclectic surgery, starting from the setting of the anterior palatoplasty first described by K. Pang [5], and subsequently adapted to the barbed surgery by F. Salamanca [7], and from Functional Expansion Pharyngoplasty described by G. Sorrenti [4].

31.2 Patient Selection

Each patient undergoes a complete clinical and instrumental evaluation:

- Administration of questionnaires (Epworth Scale, Snoring VAS, SQ).
- BMI and Neck circumference measurements.
- Upper Airways (UA) clinical evaluation: tonsillar grading, Mallampati Grading, Freedman Grading, palatal shape, dental occlusion, evaluation of nasal septum, turbinate volume, nasal masses, adenoids.
- Fibrolaryngoscopy with Muller's maneuver.
- Pre- and post-operative polysomnographic parameters.

– Cone beam CT scan or lateral cephalogram for cephalometric analysis powered by *Dolphin Imaging Software:* PAS, Bx and PNSx.
– DISE with transoral and transnasal fiber-optic endoscopy: site, grade, and pattern of collapse classified according both to VOTE and NOHL; secondary collapses (mandibular pull-up and chin lift maneuvers).

31.2.1 Contraindications to Palatal Barbed Surgery

Definitive contraindication to palatopharyngeal barbed surgery are craniofacial anomalies which could benefit most from bimaxillary advancement, secondary collapses that can be solved with mandibular devices and BMI > 35 kg/m^2. In patients with a first class obesity (BMI = 30–35 kg/m^2) a weight loss protocol has been initiated before surgery and in case of moderate-severe OSHAS, CPAP therapy is administrated too.

31.3 Surgical Techniques

Surgery is always performed under general anesthesia with oral endotracheal intubation. The patient is placed in supine position, the head is extended, and a mouth gag is placed in order to expose the oropharynx. The surgeon is placed behind the patient's head. Pre- and post-operative palatal measurements have been collected by a soft surgical ruler. Among the various types of sutures available, we usually prefer the 2-0 and 3-0 **Filbloc (Assut Europe, L'Aquila, Italy)** uni- and bi-directional barbed sutures that have remarkable advantages: available in different molecules, long- or mid-term absorption, different sizes, multiple final lock systems, high tightness with a constant stress distribution along the tissues. In all cases, uni- and bi-directional self-retaining monofilament sutures, 2-0 and 3-0 of caliber, with ½ circle non-traumatic needle, have been used. The company was requested to produce the bi-directional wire with 2 mm barbell inversion space and 45 cm of total length. The unidirectional sutures are provided by a PGCL button, 25 cm of length.

31.4 Barbed Anterior Palatoplasty (BAPP): Basic Variant

31.4.1 Indications

The indications to the classic APP are:

• Selected cases of simple snoring, mild and moderate OSAHS with anteroposterior collapse prevalence, observed during DISE.
• Tonsillectomy is never associated to this procedure; in patient with III–IV grade of palatine tonsils hypertrophy, according to Brodsky score, a tonsil volume reduction using a coblation device can be performed.

Step 1 (Fig. 31.2a) The surgical procedure begins with the drawing of the surgical landmarks directly on the palate with a dermographic pen: posterior nasal spine (**PNS**), Hamulus (**H**), and pterygomandibular raphe (**R**) are marked. A vertical line between PNS and uvula apex (**line 1**) and a horizontal line passing through the apex of the palatine arches (**line 2**) are outlined. Two other vertical lines passing through the free margin of the anterior palatine arch on both sides (**line 3**) are drawn, representing the transition point between the Superior Constrictor muscle (SC) and Palatopharyngeus (PP) fibers that must not be passed during mucosal streep harvesting. The point ***a*** is the midpoint between PNS and line 2.

Step 2 (Fig. 31.2b) The rectangular strip of palatal mucosa to be removed is outlined according to some precautions:

- Lines 3 represent the lateral limits.
- The maximum height shall not exceed 6 mm (of which 2/3 lower and 1/3 higher to the ***a*** point) because, once the minor salivary glands layer has been removed, the exposure field of the muscle plane gets naturally wider. The drawing of the mucous rectangle could usually be adapted in width and position to the needs of each specific case (for example in simple snoring a narrower rectangle is performed to suspend only the central part of the velum).

Step 3 (Fig. 31.2c) A bi-directional 3/0 or 2/0 Filbloc® barbed suture is used to tension the palatal velum and to close the palatal mucosa at the same time. The needle is introduced at the PNS and the wire is brought to the inversion point of the barbs. The following stitches start from the midpoint towards the lateral anchoring points (**H, R**) passing through the muscles of the velum and, on the way back, through the mucous flaps that must be engaged to facilitate their closure. In order to avoid exposure of the wire in the oral cavity, it is advisable to re-enter the needle always through the previous exit point.

Step 4 (Fig. 31.2d) From the PNS the wire runs through the muscles of the palatine velum and reaches the superior edge of the mucosal rectangle (1), re-enter at the same exit point and width proceeding under the PG muscle to the palatine vault (2). In the next step, the wire reaches the Hamulus passing through the inferior edge of mucous rectangle (3, 4). The needle slides inferiorly to the superior groove of the tonsillar fossa where the PP muscle (5) is engaged. The last step anchors the suture to the upper part of the R by performing a lateral traction (6).

Step 5 (Fig. 31.2e) The surgical intervention can therefore be concluded in two ways:

– With a transmucosal passage between the PG (7) and R (8) (Fig. 31.2e **blue suture**).
– With any back stitches, from R to PNS, in a superficial plane to optimize the closure of the palatal mucosa (7–12) (Fig. 31.2e **red suture**).

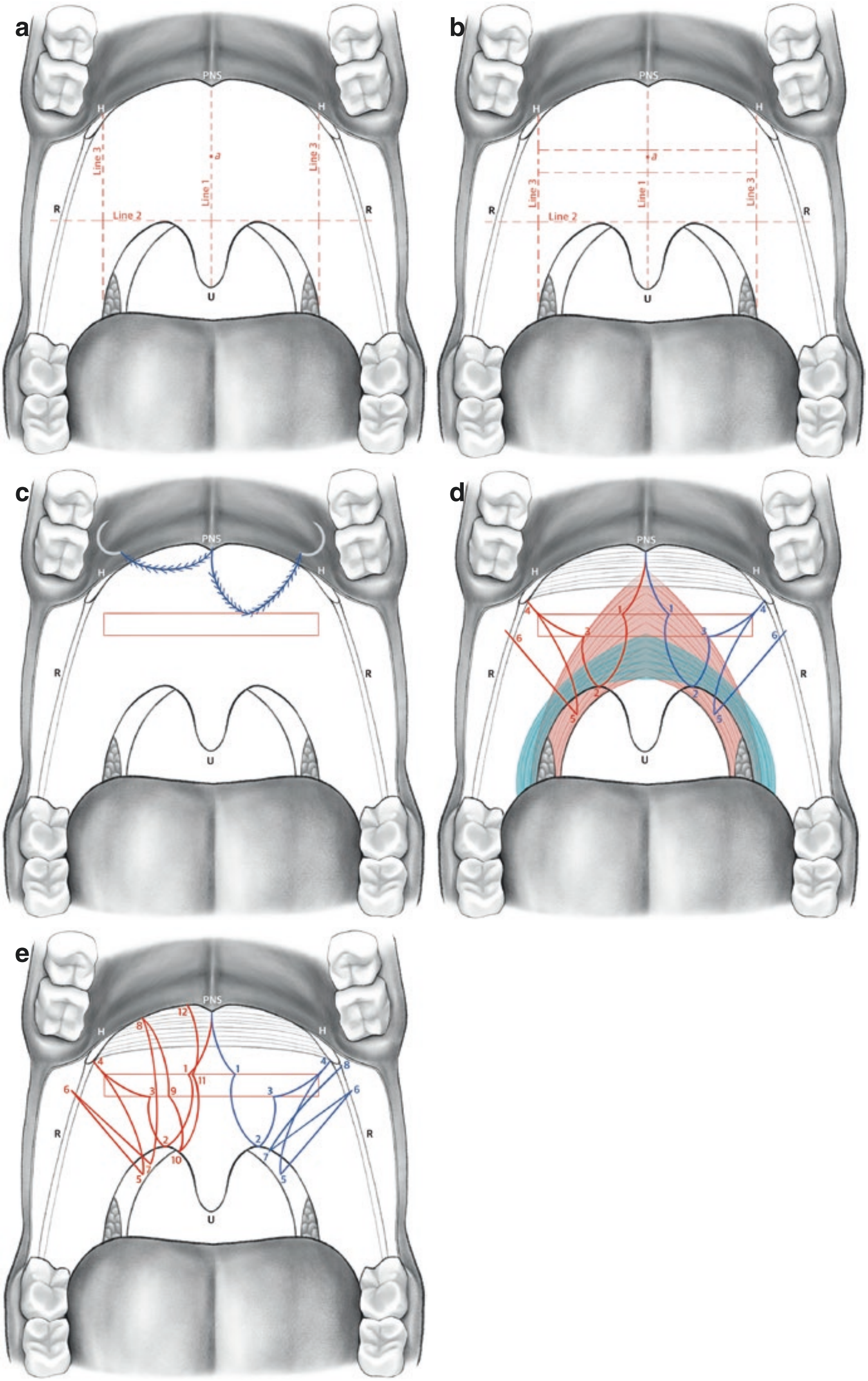

Fig. 31.2 BAPP (Barbed Anterior Palatoplasty) (**a**) preoperative planning; (**b**) palatal mucosa harvesting; (**c**, **d**, **e**) step-by-step barbed sutures positioning, all the passages are numbered

The same procedure is performed on the other side starting from the PNS, using the remaining half of bi-directional barbed suture. At the end of the procedure, the stitches are cut.

31.4.2 Considerations

- The barbed sutures shall be used exclusively to determine structural and functional modifications, limiting the final amount of wire used in the palatal tissue.
- In order to close the mucosal breach, at the end of the barbed suture, we recommend the use of a PGA braided and coated, mid-term absorption, 3/0 Assufil® suture, avoiding the excessive use of barbed sutures to reduce the risk of exposure in case of dehiscence of the wound.
- We suggest to remove a small strip of mucosa to create an access door to the velum muscles.
- The increase of the retro-palatal space and the slightest tendency to collapse are obtained thanks to the engagement of the muscles, the tensioning with the barbed sutures, and the correctly planned scar vectors.

31.5 Tonsils Sparing Antero-Lateral Barbed Pharyngoplasty (TSALBP) (Fig. 31.3)

31.5.1 Indications

The main indications to this surgical technique are represented by OSAHS patients with a rhinopharyngeal and/or retrovelar trivectorial or high sphincteric collapse observed in DISE. This surgical variant is advisable if tonsillar grading is 0, I, or II.

Step 1–2 In this variant we reply the first and second surgical steps of the BAPP (Fig. 31.2a, b).

Step 3 After the resection of palatal mucosa, a sub-muscular tunnel between the PG and the PP muscles is performed with a Kelly forceps (Fig. 31.3a1). The PGM is then retracted inferiorly with a vessel retractor (Fig. 31.3a2) and the lateral bundle of PPM, positioned on a deeper anatomical plane, is first isolated, tied and then transected at the level of tonsillar fossa apex (Fig. 31.3a3–5).

Step 4 (Fig. 31.3b) A bi-directional 3/0 Filbloc® suture is introduced at the PNS. It runs in the context of the velar muscles and exits below the mucous gap (1) and then turns back at the same muscular depth and exits more laterally in the palatine aponeurosis (2). The next stitch engages the muscular structures and exits at the vault of the anterior tonsillar pillar (3) and then runs towards the **H** (4). Then the needle hooks the proximal bundle of the PP (5) with a supero-lateral rotation of the muscle to the **R** (6). A further passage reaches the anterior palatine arch (7) engaging the PG and turning back to the R (8). At the end of the procedure, a back stitch runs to the PNS and the wire is cut (9).

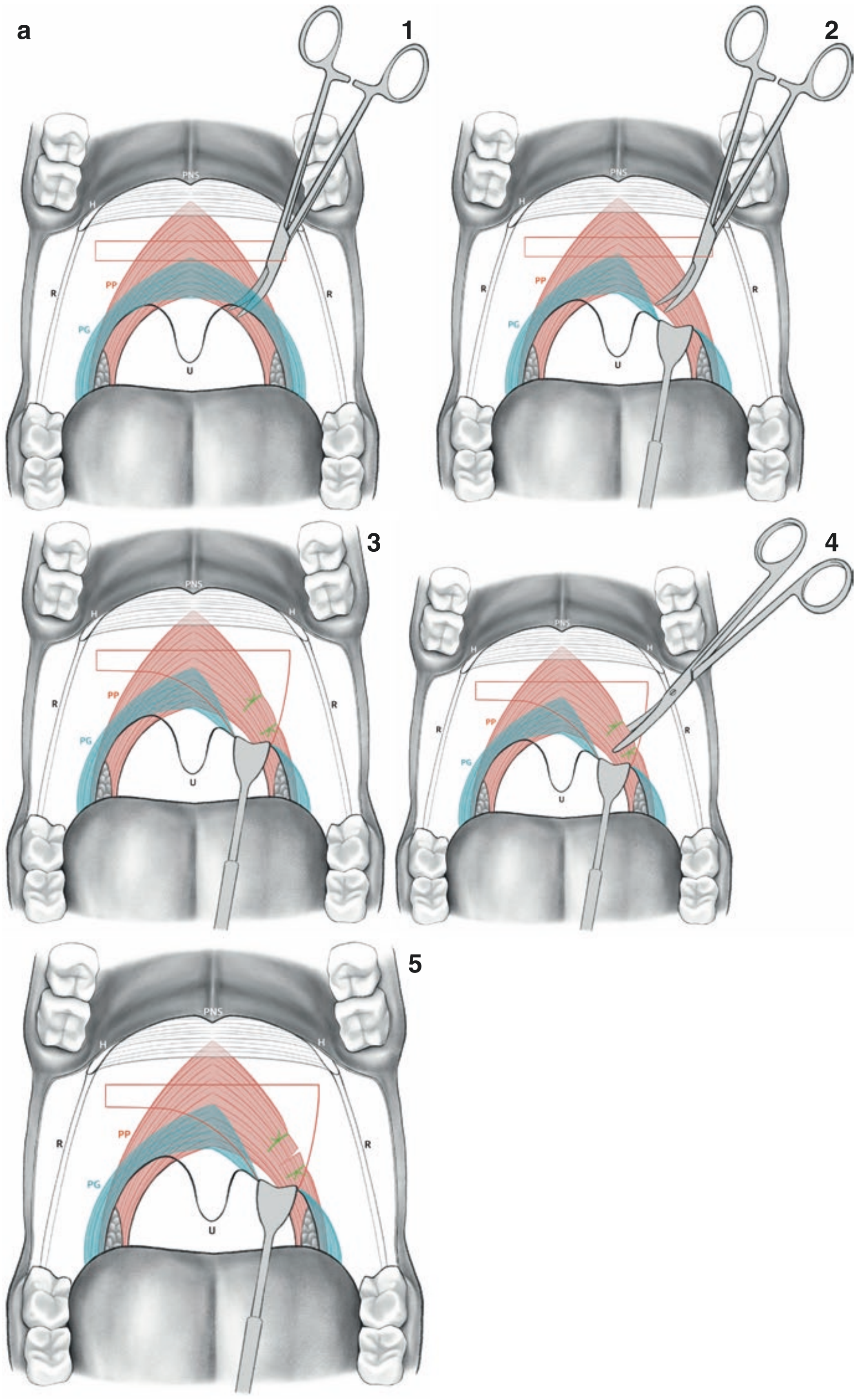

Fig. 31.3 TSALBP (Tonsils Sparing Antero-Lateral Barbed Pharyngoplasty) (**a1–5**) PP muscle isolation (**b1**) step-by-step barbed sutures positioning, all the passages are numbered

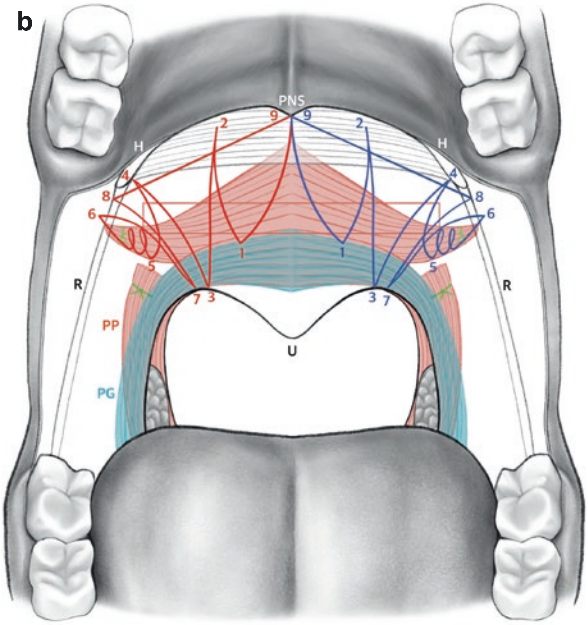

Fig. 31.3 (continued)

Starting from the PNS, the same procedure is performed on both sides. Half of the bi-directional barbed suture is used for each side.

31.6 BAPP + BSP (Barbed Suspension Palatoplasty) (Fig. 31.4)

31.6.1 Indications

The main indications to this variant are simple snoring and mild to moderate OSAHS with a severe anteroposterior collapse of the velum observed in DISE. Tonsillectomy is never performed. Coblation tonsillotomy is suggested in II–IV grade of palatine tonsils hypertrophy according to Brodsky score.

Step 1–4 In this variant, we reply the surgical steps 1 to 4 of the BAPP (Fig. 31.2).

Step 5 The wire moves, in two or three passages, from R to the contralateral one crossing the palate horizontally at uvular base (7–10). The procedure ends with a back stitch anchored to the aponeurosis (11, 12) (Fig. 31.4a).

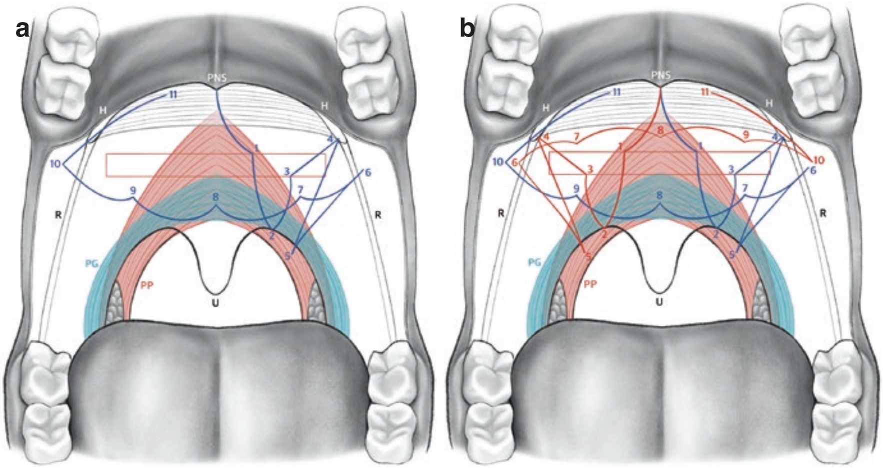

Fig. 31.4 BAPP + BSP (Barbed Suspension Palatoplasty) (**a**) left side barbed sutures positioning; (**b**) right side barbed sutures positioning

Step 6 The same procedure is performed on both sides starting from the PNS, using half of the bi-directional barbed suture for each side. The crossing passages through the palate are positioned above the mucous rectangle (Fig. 31.4b).

31.7 BAPP + BRP (Barbed Reposition Palatoplasty) (Fig. 31.5)

31.7.1 Indications

This technique is indicated in OSAHS patients with retrovelar associated to an oropharyngeal sphincteric collapse in DISE.

Tonsils must always be removed to expose the PPM in the tonsillar groove. In patients with previous tonsillectomy, it is necessary to remove a triangle of mucosa from the tonsillar lodge.

The PP is thus under direct view and it could be weakened with a kind of fraying of the muscular fibers latero-medially avoiding its complete resection to preserve the anatomical and functional meaning of the posterior tonsillar pillars (Fig. 31.5a).

Step 1–4 In this variant we reply the surgical steps 1 to 4 of the APP (Fig. 31.2).

Step 5 Starting from the R, two or three subsequent passages are carried engaging the PPM that is rotated upward and laterally (7-8-9-10) (Fig. 31.5b).

Step 6 The same procedure is performed on the other side starting from the PNS,using the remaining half of bi-directional barbed suture (Fig. 31.5b).

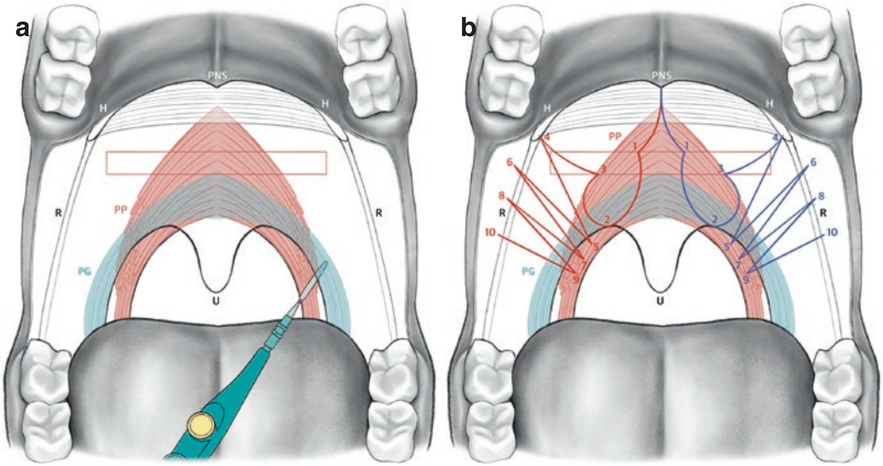

Fig. 31.5 BAPP + BRP (Barbed Reposition Palatoplasty): (**a**) Weakening of the PP muscle; (**b**) step-by-step barbed sutures positioning, all the passages are numbered

31.8 Muscle Sparing Sphincter Barbed Pharyngoplasty (MSBSP)

31.8.1 Indications

The main indications to this variant are moderate to severe OSAHS with a transversal retrovelar collapse or a trivectorial collapse with a predominant lateral vector of collapse.

As for the previous variant, tonsils must always be removed to expose the PPM in the tonsillar groove. In patients with previous tonsillectomy, it is necessary to remove a triangle of mucosa from the tonsillar lodge.

This technique permits to preserve the medial longitudinal fascicle, a portion of the lateral longitudinal bundle and the transverse fascicle.

Step 2 (Fig. 31.6a) The PPM is exposed and after a smooth dissection, the lateral bundle of PPM is isolated with the help of a cystic forceps. The medial longitudinal and the transverse bundle [12, 13] of the PPM are preserved. The muscle is tied twice and cut in its upper one third (Fig. 31.6a1–4).

At this point the surgeon can adopt one or the other variant, depending on the clinical case.

MSBSP type A (Fig. 31.6b).

A 3/0 unidirectional **Filbloc® suture** is used for each side. The needle is first introduced into the Hamulus and runs inferiorly to engage twice the previously harvested flap of PPM (1). The wire by anchoring the R (2), tensions and transposes upward and laterally the PPM flap. Another passage between R and PPM is carried out in a more lateral position (3, 4) (Fig. 31.6b). Finally, the tonsillar lodge could be

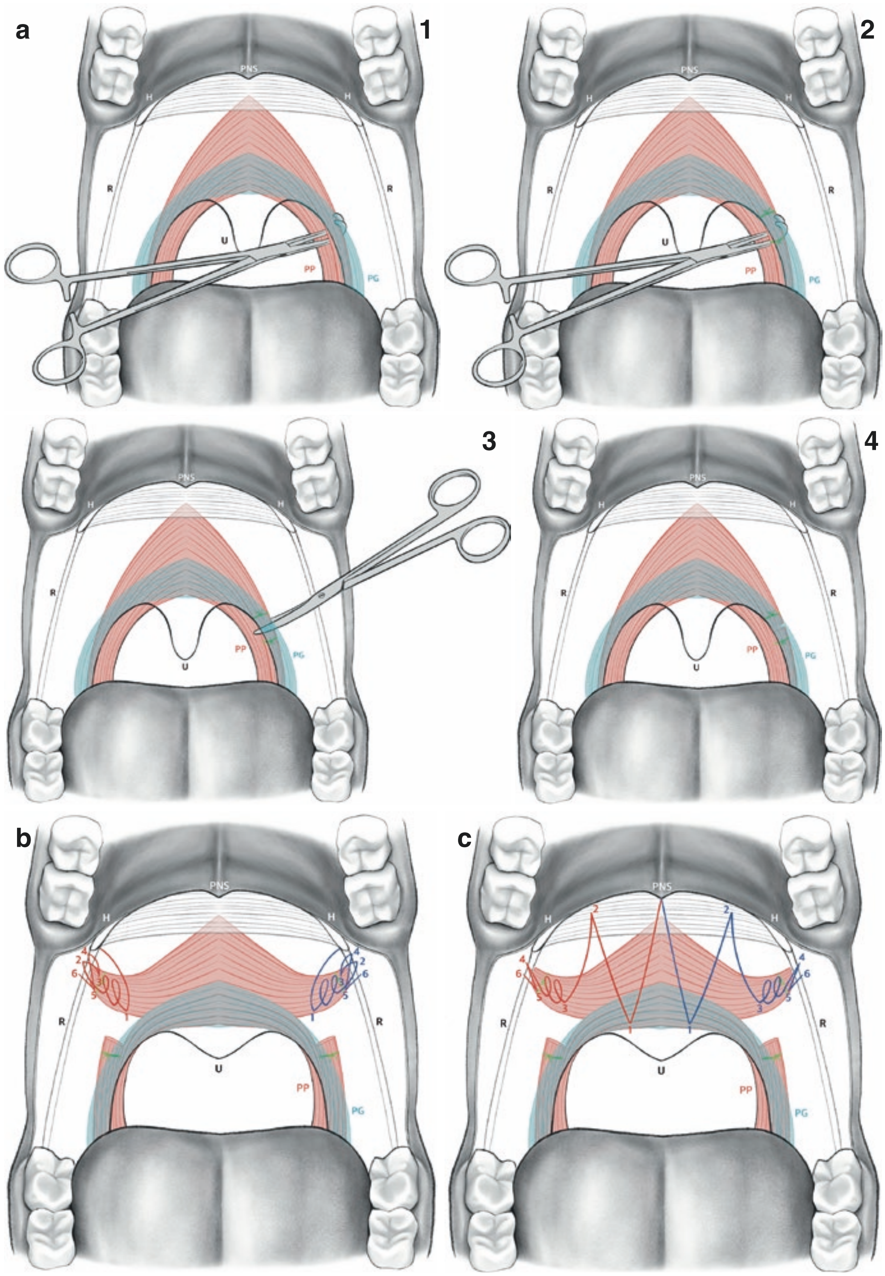

Fig. 31.6 MSBSP (Muscle Sparing Sphincter Barbed Pharyngoplasty) (**a1–4**) step-by-step PPM exposure and isolation; (**b**) MSBSP type A; (**c**) MSBSP type B

sutured with a PGA braided and coated, mid-term absorption, 3/0 Assufil® suture. This variant is helpful in case of transversal and retrovelar collapse.

MSBSP type B (Fig. 31.6c).

A 3/0 unidirectional **Filbloc® suture** (**Assut Europe, L'Aquila Italy**) is used for each side. The first stitch moves from the PNS to the palatine vault (1), then turns back to the aponeurosis (2) in order to obtain an anteroposterior tensioning and support. With another passage the PP is engaged (3) and transposed to the R (4) (Fig. 31.6c). Another passage between R and PPM is carried out in a more lateral position (5, 6). Finally, the tonsillar lodge could be sutured with a PGA braided and coated, mid-term absorption, 3/0 Assufil® suture. This variant is usually used in case of trivectorial retrovelar/superior oropharyngeal collapse.

31.8.2 Considerations

Unlike the other techniques described so far, MSBSP is not a variant of the PPA but a modification to the Functional Expansion Palatoplasty (**FEP**) [4].

31.9 Post-operative Care

Our post-operative protocol is based on the administration of antibiotics, anti-inflammatories, analgesics, and anti-oedematous. To prevent bacterial colonization and reduce inflammation, azithromycin (500 mg) is administrated once a day for the first 3 days. Thanks to an early antalgic therapy, the post-operative period is usually not very painful. During the first 12 days, central pain control is managed with oxycodone hydrochloride 5 mg + naloxone hydrochloride dihydrate 2.5 mg. We administer supplements to reduce edema and inflammation: Bromelain 200 mg + Boswellia 200 mg twice a day for 15 days. Moreover, corticosteroids are administered as anti-oedematous drug only in the immediate post-operative period. Paracetamol 1000 mg is administered as needed. The patient is usually discharged 2 days after surgery.

31.10 Complications

Barbed surgery has usually a low rate of early post-operative complications. Bleeding, suture dehiscence, and swallowing impairment are the more common immediate complications. While bleeding is at present a rare occurrence, suture dehiscence can have a not negligible incidence when the same barbed wire is used to suture the tonsil pillars. Long-term complications have not been observed in our experience and not described in literature for this specific kind of operation.

31.11 Case Series

From January 2015 to December 2020 we treated 71 patients applying the principles of eclectic barbed surgery. Inclusion criteria were: age >20 years and <70 years, body mass index BMI <35, simple snoring or apnea-hypopnea index AHI >5 as documented by polysomnography, no prior surgical intervention for sleep apnea, no combination with epiglottoplastic or partial glossectomy, and no contraindications to surgery. We collected a sample of 71 patients: 55 males and 16 female with a mean age of 47 years. Body mass index ranged from 19 to 34 Kg/m^2 with a median value of 26.5 Kg/m^2. Based on polysomnography, Our sample was classified as follows: three patients with simple snoring and 69 patients with OSHAS and a median apnea-hypopnea index (AHI) of 19,24 (range 7–56). In all patients a clear velopharyngeal collapse was observed in DISE.

We performed 13 BAPP-BRP, 7 BAPP-TSLP, 13 MSBSP, and 5 BAPP-BSP. Our results showed an overall success rate of 95% with a decrease of mean AHI from 19.24 to 6.6 and a decrease of ESS from 11.76 to 2.4. In simple snoring patients, we observed an improvement as reported by snoring assessment questionnaire (SQ) of sleep partners and snoring VAS. One patient experienced a tonsillar hemorrhage major complication. Five patients experienced minor complications such as long-lasting swelling of the uvula or of the soft palate.

31.12 Discussion and Conclusion

For patients affected by sleep apnea syndrome, Continuous Positive Airway Pressure (CPAP) must still be considered the first treatment option with the highest success rate. However, considering the high percentage of patients who initially reject CPAP, the frequency of poor tolerance in long-term ventilatory therapy and the increasingly less invasive and more effective techniques, the therapeutic indications, in selected patients, are shifting towards the surgical approach [14].

The world of OSAHS surgery has progressively accepted DISE as the gold standard for accurate diagnosis in order to achieve surgical success [11]. It allows to identify the multiple sites of obstruction, collapse patterns (anteroposterior, trivectorial, transverse, sphincteric) and quantify the degree [15]. Moreover, the use of transoral and transnasal fibreoptic endoscopy during DISE procedure, in association with maneuvers such as the mandibular pull-up, chin lift, and head/body rotation, enable us to understand whether the palatal collapse is secondary, i.e., determined by a tongue retro positioning (Fig. 31.3). In these cases, DISE has demonstrated to be useful in predicting success in potential MAD users. Finally, in case of post-surgery non-responder patients, DISE provides insights on remaining causes of UA collapse, guiding further surgical and non-surgical treatment options [16]. Once the secondary collapses of the palate or skeletal predisposition have been excluded, our aim is to describe the oropharyngeal collapse patterns and to identify the muscles bundles responsible for the collapse to define a tailored surgical treatment. Therefore, a deep knowledge of the functional anatomy [12, 13, 17, 18], the accurate interpretation of the DISE, and the comprehension of every emerging surgical concepts are the preconditions for an eclectic and personalized use of barbed sutures in sleep apnea patients. This approach gives the surgeon the opportunity to match the right pharyngeal barbed surgical procedure with the right patient (Fig. 31.1). Despite the profound changes in recent years, we can say that none of the techniques is better than the other. What we suggest is not to choose a technique to treat all cases. All the techniques described can provide us with a range of valid solutions and contain the evolutive concepts illustrated in Fig. 31.1. As shown with practical examples, these concepts could be adapted to each individual case and optimized using the most appropriate technological tools available.

According to the Montevecchi classification, a 50% AHI reduction has to be considered a surgical success [19]. Using the eclectic approach, we achieved a 95% success rate; this means that with a careful selection of the patient and respecting the evolutionary concepts, results comparable to traditional techniques are obtained with a minimally invasive impact. In MSBSP and TSALBP, characterized by the preservation of a large portion of the PPM in order to prevent a hypothetical late dysphagia, our success rate did not change. Similarly, the recombination of surgical techniques described by other authors, such as the BAPP and the BSP, has allowed to obtain an optimal stiffening of the soft palate both in patients with moderate OSHAS and in strong snorers without increasing the side effects.

Contents: All the anatomical images in this chapter are sponsored by Assut Europe L'Aquila Italy, were produced by the illustrator Chiara Donateo and are copyrighted.

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Barbed Functional Expansion Pharyngoplasty

32

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32.1 Introduction

Obstructive sleep apnea (OSA) results from the collapse of the pharyngeal airway during sleep. The etiology and mechanism of collapse are multi-factorial but are mainly due to the interaction of an easily collapsible upper airway (UA) with the relaxation of the pharyngeal dilator muscles which happens during sleep [1, 2]. Moreover, OSA can be related to anatomic abnormalities causing UA narrowing [3]. Drug-induced sleep endoscopy (DISE) has become popular worldwide as the preferred diagnostic tool to assess the UA while sleeping, revealing the key role of the lateral pharyngeal wall (LPW) collapse in the pathogenesis of OSA [4–8].

Accordingly, new surgical techniques in which the LPW is specifically addressed have been reported since 2003, when Cahali published first lateral pharyngoplasty technique based on sectioning of the superior pharyngeal constrictor muscle [9].

In 2007, Pang and T. Woodson [10] described an innovative technique (ESP) for creating tension in the LPW and widening retro-palatal diameters. The key point of this technique is the rotation and anchorage of the palate-pharyngeus muscle (PPM) to some steady holds such as the pterygoid hamulus (PH) and pterygo-mandibular raphe (PMR). These anatomical structures represent a stiff support which provides the high tensile strength required to suspend the PPM and to prevent collapse of the UA.

In 2012 [11], we described a modified ESP technique (Functional Expansion Pharyngoplasty—FEP) that represents a less aggressive and more “physiologic” approach to the LPW and soft palate to both increase pharyngeal airspace and decrease pharyngeal collapse, without undermining velum muscles, and in doing so avoiding scarring of the velum and uvulectomy.

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_32

To improve the biomechanical effect of sutures on tissue collapse, the use of knotless barbed sutures, extensively used in plastic surgery, has been recently described in sleep apnea surgery.

Several types of barbed threads are available commercially, each of which has unique feature and insertion technique. We first introduce the use of unidirectional barbed sutures for lateral pharyngoplasty [12]. This technique is a new simple variant of our FEP technique.

32.2 Surgical Technique

Surgery is performed under general anesthesia with oral endotracheal intubation. The patient is placed in a supine position with the head extended and a mouth gag is then used to adequately expose the oropharynx.

The first step is bilateral tonsillectomy with identification and meticulous sparing of the palato-pharyngeus muscles (PPM). The PPM is isolated from the mucosa and superior pharyngeus constrictor (SPC) muscle and transected in the midpoint of the tonsillar fossa, creating a muscle flap with superior and medial pedicle. The posterior surface of the cranial portion of the PPM is partially left attached to the SPC.

By means of unidirectional barbed sutures, the needle is introduced in the maxillary tuberosity turning around the pterygoid hamulus [13] (PH) (Fig. 32.1) and performing a U-shaped stitch engaging the terminal loop of the thread (Fig. 32.2). The needle is then inserted downwards and laterally to the pterygo-mandibular raphe (PMR). Once the needle reached the apex of the tonsillar fossa (Fig. 32.3), it was driven through the PPM flap (Fig. 32.4). This stitch is repeated at least three times by different directions. The needle is reinserted through the flap and directed laterally to the PMR (Fig. 32.5). Applying the right amount of tension to the wire pulls the flap upwards and laterally, increasing the oropharynx diameters as well as the soft palate stiffness. Afterwards, the needle is introduced laterally to the PMR piercing through the posterior tonsillar pillar (Fig. 32.6). Finally, the suture grasps and suspends the posterior pillar and returns back in a point laterally to the PMR (Fig. 32.7). Based on appropriate tension of the suture, complete or partial closure of the tonsillar fossa can be obtained minimizing the risk of bleeding and wound dehiscence. In the last step, the thread is locked around the maxillary tuberosity periosteum (Fig. 32.8). The barbed wire is pulled and cut close to the mucosa without the need for any knot.

Operation time is about 40 min.

Several types of barbed threads are available commercially, each of which has unique feature and insertion technique.

For this technique we use a unidirectional barbed absorbable suture with a terminal loop (V-Loc™ 90 2.0, Covidien Healthcare, Mansfield, MA). The V-Loc suture is characterized by unidirectional shallow barbs with circumferential distribution. Its dual angle barbs allow stronger anchoring force and higher maximum load compared to other barbed sutures and the shallow cut-depth preserves the integrity of the

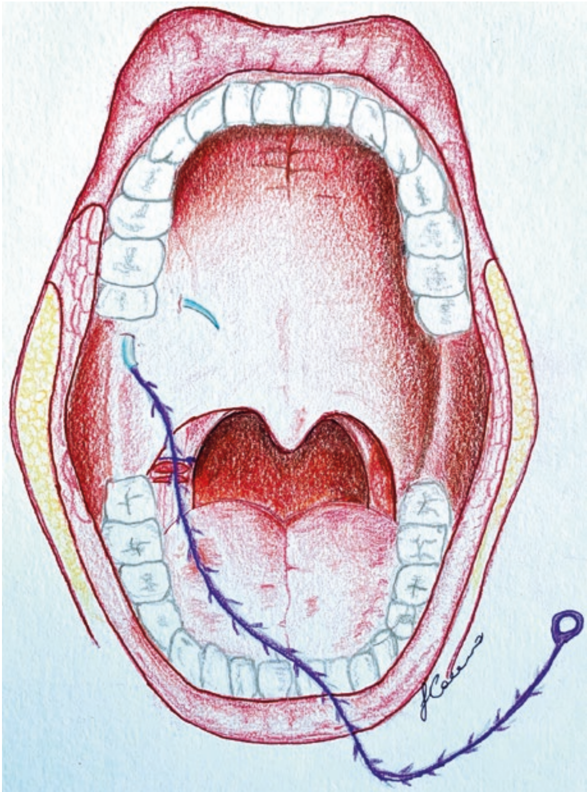

Fig. 32.1 The needle is introduced in the maxillary tuberosity turning around the pterygoid hamulus

strand's strength over time. This thread generally undergoes complete absorption 90–110 days after surgery.

32.3 Indications

In our protocol, the surgery originates from a diagnostic workup completed by DISE. We currently see an indication for barbed FEP in case of single clinically significant (>75%) oropharyngeal airway obstruction related to lateral wall collapse as assessed by sleep endoscopy, no craniofacial anomalies and morbid obesity (BMI > 40).

32.4 Postoperative Care

The patients can start a soft oral diet on the first postoperative day and a normal diet after 10–15 days. Postoperative paracetamol plus codeine may be useful for analgesia after surgery.

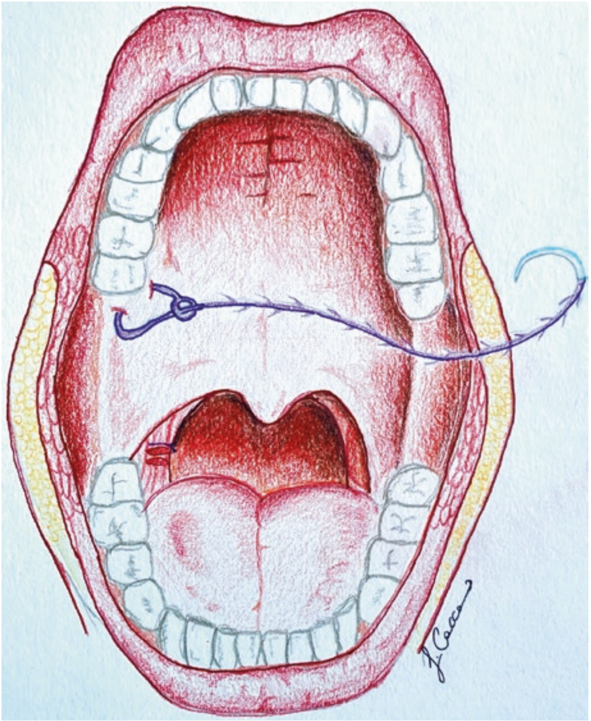

Fig. 32.2 The needle performs a U-shaped stitch engaging the terminal loop of the thread

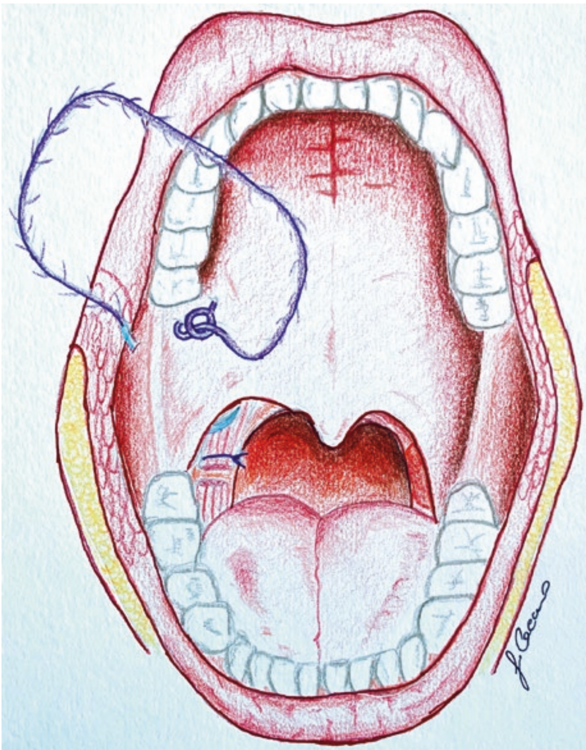

Fig. 32.3 The needle is inserted downwards and laterally to the pterygomandibular raphe reaching the apex of the tonsillar fossa

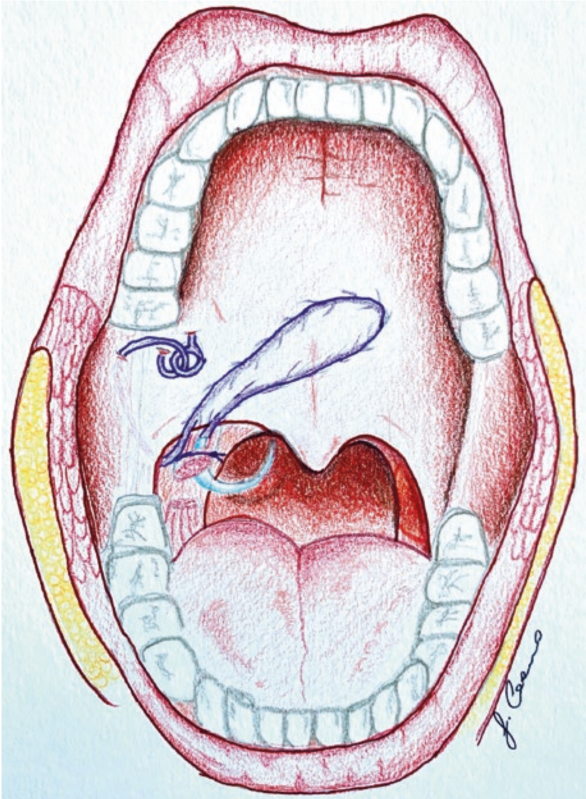

Fig. 32.4 The PPM flap is engaged by the needle for three times in different directions

To prevent infections, we recommend antibiotic therapy for 5–7 days (i.e., amoxicillin clavulanate). In some cases, corticosteroids are needed to reduce postoperative swelling.

32.5 Complications

We did not observe serious complications related to this surgery. No cases of suture dehiscence were observed. No dysphagia or swallowing disturbances were referred at long-term follow-up.

Some patients reported dry mouth and globus sensation, but those complaints had subsided by 1 month. Postoperative bleeding was rare (2.2%).

32.6 Surgical Outcomes

We treated 90 patients (male-female ratio: 84–6) with a mean age of 46.9 (range: 20.0–71.0) years and mean body mass index of 28.5 (range 22.6–35.0) Kg/m^2. Twenty-six (28.9%) patients had moderate OSAS and 64 (71.1%) had severe OSAS, while 80% of patients had small tonsils (grade 1 or 2 according to Brodsky score).

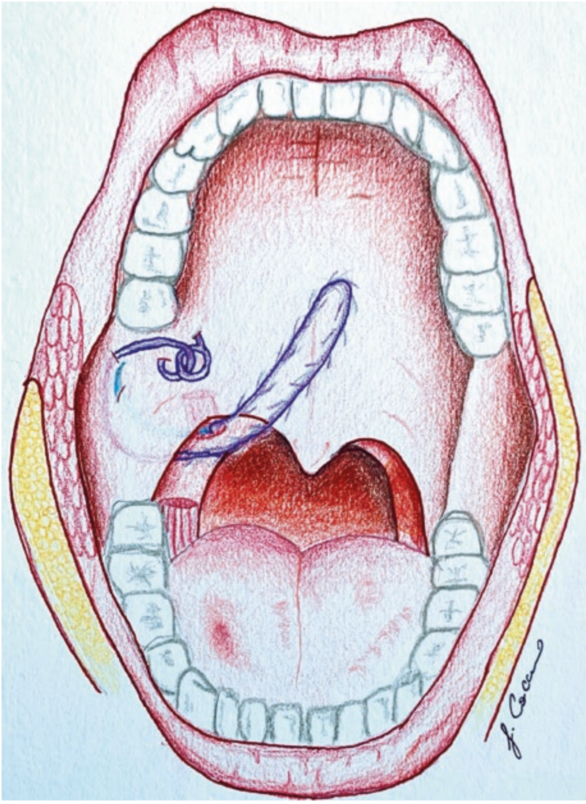

Fig. 32.5 The needle is reinserted through the flap and directed laterally to the pterygomandibular raphe

In all cases, the site and pattern of collapse was assessed by DISE and scored using the VOTE classification.

Success criteria were defined as 50% reduction in apnea–hypopnea index (AHI) and an AHI less than 20/h [14]. A total of 68 patients (75.6%) met the surgical success criteria. The mean AHI decreased significantly from 42.6/h (± 19.2) to 11.6/h (± 10.4)—(mean difference, 31.1; 95% CI, 27.3–34.8; $p < 0.001$). Also, the PSG oximetry parameters improved significantly. The mean lowest O_2 saturation ($LsatO_2$) increased from 79.0% to 86.2% (mean difference, −7.1; 95% CI, −8.8/−5.4; $p < 0.001$) while the mean time with oxygen saturation <90% decreases from 12.8% to 2.9% (mean difference, 9.9; 95% CI 6.7–13.0; $p < 0.001$). Excessive daytime somnolence also improved after surgery, with ESS decreased from 9.9 to 4.7 (mean difference, 4.7; 95% CI 3.8–5.5; $p < 0.001$).

To determine predictors of surgical success clinical parameters (BMI, neck circumference, MPH, ESS), DISE findings and polysomnographic data were analyzed.

Multivariate analysis showed that lateral pharyngeal wall collapse, as assessed by DISE, was the only significant predictor of positive response to surgery ($p < 0.001$). Considering patients with isolated velo-oropharyngeal obstruction, the success rates grow up from 75.6% to 89.5%. In contrast, retro-palatal complete

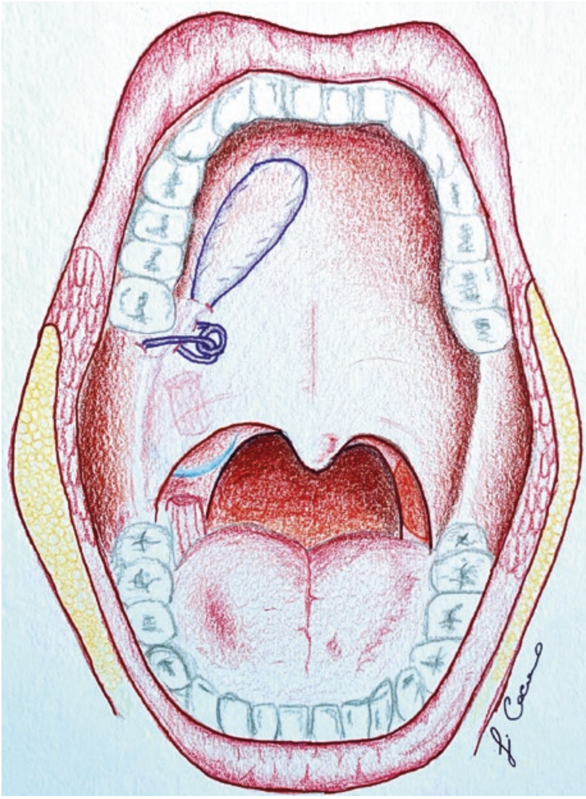

Fig. 32.6 The needle is reintroduced laterally to the pterygomandibular raphe reaching the apex of the tonsillar fossa

concentric obstruction and multilevel collapse was associated with poor outcome ($p < 0.001$) and only 50% of patients meet booth success criteria. All other parameters have no predictive value, although we noticed that lower MPH value had a positive trend associated with a good surgical success without achieving statistical significance ($p < 0.07$). In conclusion, DISE is a useful tool for predicting success rate of pharyngeal surgery and to select patient's candidate to combined treatment.

32.7 Concluding Remarks

This technique is a new simple variant of FEP described in 2012. The operation consists of barbed sutures inserted through the fibromuscular soft palate tissue in such a way that they lift and stiffen the excessively collapsing structures [15]. The threads are suspended to specific fibro-osseous anchor points which provide the high tensile strength required to suspend the soft tissue and to prevent collapse [16, 17]. After gradual resorption of the barbed threads, collagen synthesis is continuously stimulated, leading to the formation of scar tissue that will further contribute to the retraction and maintenance of the soft palate tissue in the desired position.

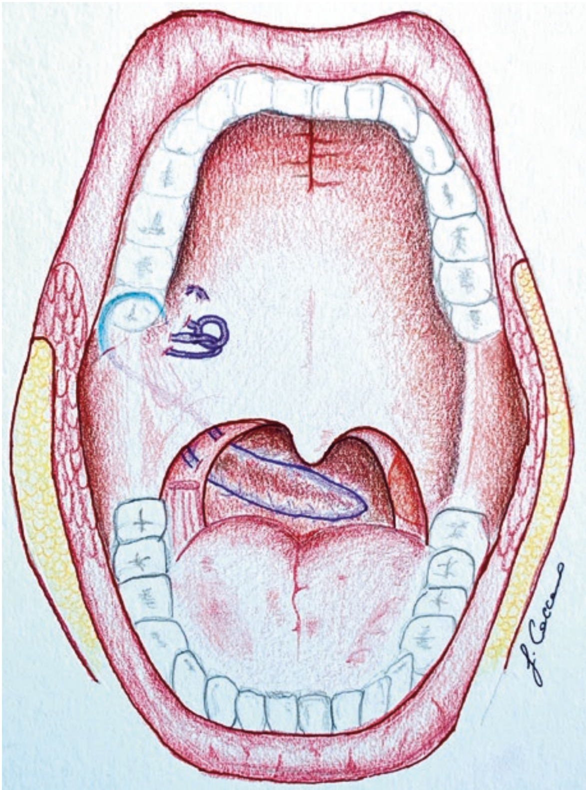

Fig. 32.7 The needle with a U-shaped stich grasps and suspends the posterior pillar and returns back

Furthermore, considering that in palate surgery completeness of suturing is very important to reduce the risk of dehiscence, barbed sutures offer reduction of bulk at the repair sites without redundant knots as a potential weak point. The minimal required manipulations and the knotless technique mean that, for the inexperienced surgeon, this is a technique that is easy to learn, and that can be performed quickly and safely. The use of barbed suture threads also leads to a complete closure of the tonsil fossa which makes postoperative hemorrhage a rare occurrence. Another benefit is that barbed sutures permit adoption of an individualized tailored approach in each patient.

The surgical outcomes obtained so far present an excellent success rate associated with an improvement in subjective symptomatology.

The DISE represents an important diagnostic tool that allows to select and distinguish patients who have an isolated lateral oropharyngeal collapse, which when recognized is associated an elevated surgery success rate, from those that present multilevel collapse or retro-palatal complete concentric obstruction which have poor surgical results and should be candidates for combination treatments.

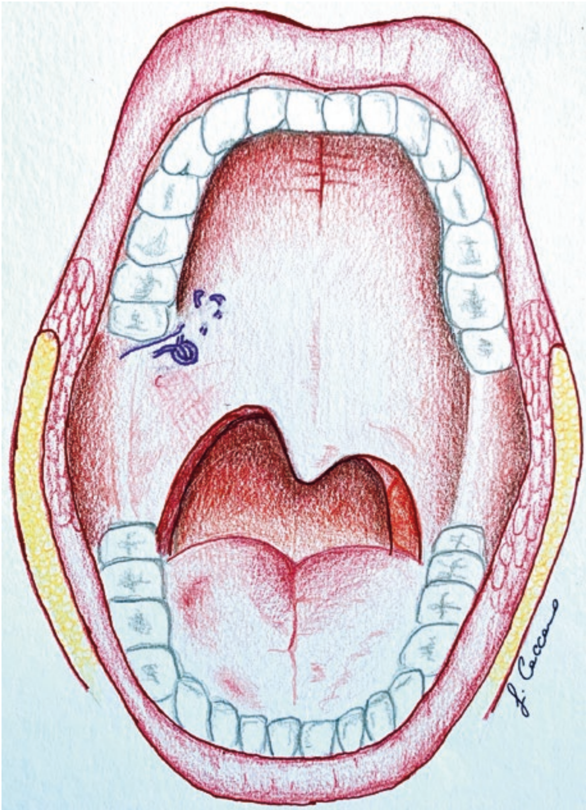

Fig. 32.8 The thread is locked around the pterygoid hamulus with a supero-lateral widening of oropharyngeal space and closure of the tonsillar fossa

Acknowledgments All the images present in this paper were made by Dr. Giuseppe Caccamo (Department of Otolaryngology-Head and Neck Surgery, Bologna, University Hospital) coauthor of this chapter.

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Simplified Barbed Reposition Pharyngoplasty (sBRP)

33

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33.1 Definition

Surgical treatment of OSA utilizes different and specific options for each level of upper airway obstruction [1]. One of the surgical options [2–5] for patients with obstruction at the retropalatal level is pharyngoplasty with repositioning, by means of barbed threads (BRP), which has proven to be an effective and safe technique [6, 7] and has been widely successful for several years [8, 9].

This technique uses suture materials (Knotless Tissue-Closure Device) [10] never used before in surgical therapy for OSA and first proposed and applied by M. Mantovani [11, 12].

In a recent publication [13], we presented results obtained using a variant of the BRP technique termed sBRP (simplified BRP). This technique involves separate and independent management of the two pharyngeal side walls using a single-needle resorbable barbed thread on each side as a wound closure device [10]. In addition, the simplified procedure involves the elimination of the last step of the surgical procedure proposed by Vicini et al. [6].

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_33

The sBRP is a simplification of the technique that looks at the needs of the less experienced surgeon, thus aiming at a greater diffusion of the BRP. The technique in fact comes from the experience gained from dissection courses and didactic simulations of cadaveric surgical techniques at palatal level for OSA patients [14–18].

In addition, the simplified technique has no difference from the already known BRP protocol from which it is derived.

33.2 Equipments

We prefer our own custom surgical instrument set for both BRP and sBRP, although a standard tonsillectomy equipment in cold steel is appropriate. A monopolar and bipolar diathermy is always available.

For sBRP, we use a unidirectional knotless device for wound closure, barbed double angle, absorbable, made of copolymer of glycolic acid and trimethylene carbonate 30 cm, single needle, 37 mm needle, 1/2 circle, size 0, taper) (Covidien V-Loc 180™) [10] (Covidien IIc, Mansfield, MA, USA).

A standard tracheotomy set is always available and ready to use for emergency situations.

33.3 Anesthesia and Patient Positioning

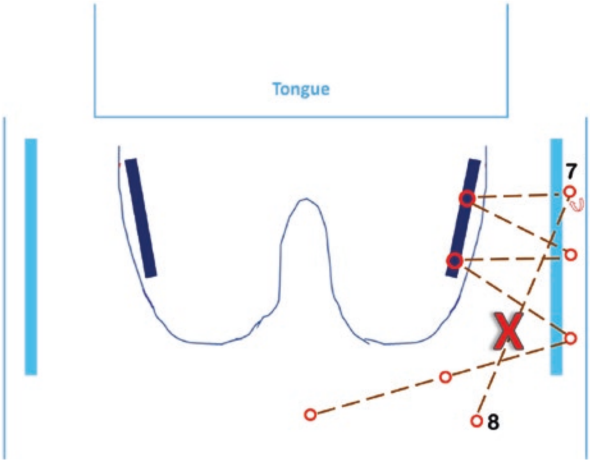
sBRP is performed exclusively under general anesthesia with the patient nasally or orally intubated, lying in supine position with the head slightly extended and positioned “à la demande.”

33.4 Surgical Procedure and Steps

In patients who retain their tonsils, a preliminary bilateral tonsillectomy is performed with sparing of palatopharyngeus muscles. Monopolar or dipolar diathermy is used in the same way as BRP.

1. In the sBRP, we used the wound suture device [10] previously mentioned for each side. This tissue-closure device was used in place of the double-needle absorbable bi-directional monofilament suture thread recommended in the original description of the BRP method to suture both lateral walls of the pharynx.
2. Using an analogous barbed double-angle, unidirectional, single-needle, absorbable suture thread, we similarly performed the sBRP procedure on the opposite side, taking care to balance and manage the pooling force between the two sides.
3. The sBRP procedure stops at step 7 and does not continue to step 8 as in the case of the BRP procedure (Fig. 33.1).
4. In all cases of sBRP, an additional suture loop was performed to reinforce step 7.

Fig. 33.1 On the right side, the simplified BRP procedure with abolition of step 8 compared to the standard BRP procedure. Pterygomandibular Raphe (light blue). Palatopharyngeus Muscle (dark blue)



Through the sBRP procedure, it is possible to combine the simplification of the technique without having significant changes on the postoperative polygraphic results at 6 months [19] (see Sect. 33.5).

This was achieved by using barbed sutures equipped with dual-angle technology that exert a strong anchoring force on the soft tissues. In fact, suturing the two sides of the pharynx separately allows for better management of calibration and balancing of poolinig forces on the soft tissues. This creates synergism with the strong pulling force exerted on each side by the dual-angle technology [20].

The use of a unidirectional suture—single needle—for each pharyngeal side wall also allows for greater freedom in choosing the points of application of traction forces and thus the vector magnitudes applicable in each side. This separate management of the collapsibility of the lateral wall therefore can compensate for possible asymmetries due to inaccuracies of surgical technique.

The last step of the standard BRP procedure has been eliminated. Although this is a procedure that is essentially easy to learn, a critical moment for the inexperienced surgeon is the performance of the final step. The elimination of step 8 also seems to be able to reduce one of the minor complications that is the dehiscence [21] of the suture in that location.

With the elimination of the last step of the standard BRP procedure, a key vector is eliminated and replaced by an additional reinforcing loop of suture between the pterygomandibular raphe and palatopharyngeal muscle. In this way, although we eliminated the parasagittal vector, we had no negative impact on polygraphic outcomes at 6 months postoperatively [13].

No differences were noted with sBRP in a series of 49 patients compared with the BRP method from which it is derived in the following 6 months postoperatively.

33.5 Success Rate

In our recent study [13], 99 patients were recruited within the sleep apnea surgery protocol. Patients underwent drug-induced sleep endoscopy (DISE) by *5VsEs* procedure [22, 23] from April 2015 to December 2019, in order to confirm the diagnosis of single-level palatal OSA.

A verification of the functional results obtainable using sBRP was performed by comparing pre- and post-surgery polygraph data on a sample of 49 patients treated with sBRP and 50 patients treated with BRP as a control.

In this study, we collected the pre- and post-surgery polygraphic data (Apnea Hypopnea Index (AHI), (hour/sleep), Oxygen Desaturation Index (ODI), (hour/sleep), Lowest O_2 saturation, (%)). We based on AASM guidelines 2007 to make the results of our study comparable with previous literature [24].

The surgical procedure regarding the standard BRP group was performed respecting the surgical technique published by Vicini et al. [6].

The aim of this analysis is to evaluate the statistical differences between pre-surgery and post-surgery per each group (BRP: Group A and sBRP: Group B) and the statistical difference between BRP and sBRP in both the previous conditions. A two-sample bootstrap t-test [25] is performed on the following variables: AHI, BMI, ESS, Lowest SpO_2, ODI.

The whole sample is divided in Group A (BRP, $n = 50$) and Group B (sBRP, $n = 49$) and the means per each variable were compared via two-sample bootstrap t-tests method, showing a substantial overlap in polygraphic results recorded 6 months after surgery.

Figure 33.2 shows the box plots for both experimental conditions (BRP: Group A and sBRP: Group B) for the phases of the surgery (pre and post) considering all the variables. For both experimental conditions all the measures decrease, with the exception of Lowest SpO_2, showing also a reduction of the variability and an improvement of stability of the measures.

Tables 33.1 and 33.2 report the results of a bootstrap paired *t*-test for both within each Group BRP and Group sBRP. The rows represent the variables and the columns the means differences, *t*-test, confidence intervals, and *p*-value. In both the experimental conditions (Tables 33.1 and 33.2), the differences between the means of pre-surgery and post-surgery are statistically significant for all the variables, with the only exception of the BMI.

The results show that the operation reduces all the parameters analyzed, only Lowest O_2 increases, with an improvement of the general health conditions.

Moreover, the bootstrap test is performed between Group BRP and Group sBRP reporting with a p-value >0.05, thus for all parameters examined, there is no significant differences between the means. Regarding the functional results, the bootstrap means comparison between Group BRP and Group sBRP in the parameters examined (AHI, ODI, and Lowest O_2) pre-surgery and post-surgery phases showed no statistically significant differences.

The polygraphic results at 6 months seem to support the validity of the simplifications of the technique and confirm one of the peculiar characteristics of BRP,

Fig. 33.2 Box plots pre-post analysis per BRP (Group A) and sBRP (Group B) [13]

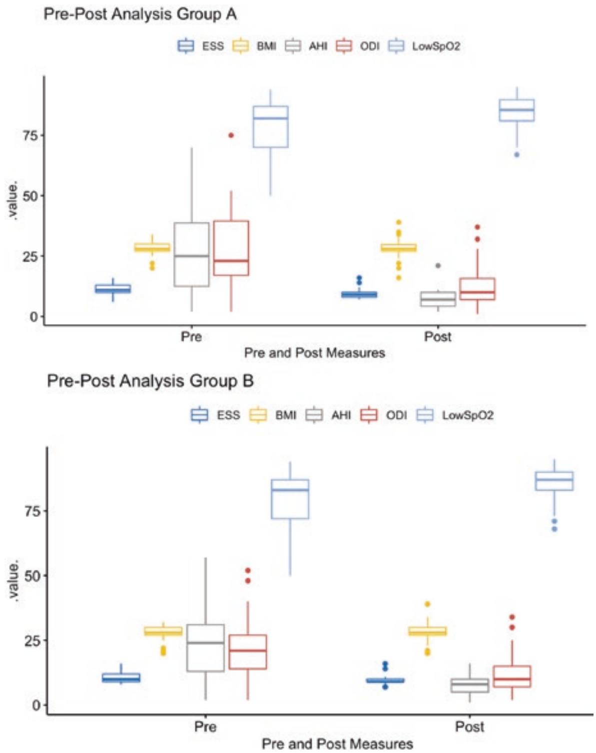


Table 33.1 Bootstrap paired *t*-tests. Group BRP

Variable	mean of the differences	*t*	2.5%	97.5%	*p*-value
ESS	−1.68	−7.382	−2.14	−1.26	0
BMI	−0.42	−1.130	−1.16	0.28	0.278
AHI	−19.1	−9.334	−23.16	−15.179	0
ODI	−14.68	−8.139	−18.3	−11.22	0
Low SpO_2	6.18	5.619	4.18	8.38	0

Table 33.2 Bootstrap paired *t*-tests. Group sBRP

Variable	mean of the differences	*t*	2.5%	97.5%	*p*-value
ESS	−1.551	−5.836	−2.082	−1.041	0
BMI	−0.224	−0.688	−0.816	0.449	0.564
AHI	−16.184	−10.294	−19.367	−13.204	0
ODI	−10.204	−7.131	−13.061	−7.510	0
Low SpO_2	5.633	5.066	3.592	7.857	0

which is that of being a procedure that allows the surgeon a certain freedom in its execution. In fact, these results indicate the effectiveness of the BRP methodology even in this simplified BRP form.

In addition, the separate management of the two sides of the pharynx in the simplified form facilitates the solution of intraoperative problems typical in the use of the barbed suture, e.g., a damaged needle or a misplaced barbed suture [12]. In the cited study, only one patient in the standard BRP group had suture exposure. No patient in the sBRP group had suture exposure [21].

33.6 Limits

To date, we have no long-term polygraph data regarding this new simplified version of BRP and it is clear that further studies are required to compensate for the lack of long-term patient follow-up and to increase the size of the study sample population.

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34 Different Barbed Pharyngoplasty Techniques for Retropalatal Collapse in Obstructive Sleep Apnoea Patients: A Systematic Review

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34.1 Introduction

In the last 20 years, the surgical management of Obstructive Sleep Apnoea (OSA) and snoring has undergone continuous expansion and refinement. As surgeons gained more information about airway's mechanisms and physiology, many new procedures have been developed that are tailored for reconstruction and stabilization of not only specific airway level but also of particular collapse mechanisms within each level. The surgical intra-pharyngeal technique for OSA has transformed the radical excision of "redundant" soft tissue for the enlargement of the airways to a minimal-invasive reconstruction to fulfil both preservation of pharyngeal function and improvement in sleep apnoea and snoring. To reduce the invasiveness of existing surgical procedures, Mantovani et al. [1] introduced Barbed Sutures (BS) in pharyngoplasties for the treatment of snoring and/or OSA. BS are knot-free self-blocking threads characterized by the presence of directional projections (or barbs) along the entire length, which imparts tensile strength inside the tissues without the need to tie a knot [2]. These types of threads are usually resorbable within 90–180 days, allowing for fibrosis of the tissues that will preserve the functional results. Related to these unique advantages, some of the most popular pharyngoplasty techniques have been updated with BS. These newer procedures tend to be less invasive or morbid, thus improving acceptance by patients, which, if matched

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_34

with improved outcomes, makes OSA surgery a reasonable therapeutic tool for OSA management in selected patients. This chapter has been designed to analyse and report the results of all the Barbed Pharyngoplasties (BPs) described in the literature: the first section is dedicated to the studies supporting BP as an effective therapeutic surgical option for the of OSA patients, whilst the second part analyse the current evidence on the clinical effectiveness of BP for snoring.

34.2 Results

BP can be performed alone or as part of multilevel surgery for the treatment of OSA and/or simple snoring adult patients. For each study we evaluated the OSA severity with Apnoea Hypopnea Index (AHI) post-operative improvement and surgical success rate where indicated (according to Sher's success criteria [3] defined as post-operative reduction in the AHI of C50% and/or a post-operative AHI of 20/h).

34.2.1 Barbed Pharyngoplasty for Sleep Apnoea

About the management of patients with mild to severe OSA many authors had shown the efficacy of BP. In 2015, Mantovani et al. [4] first introduced the use of BS investigating the effects of the "Barbed Roman Blinds Technique" (BRBT) in 32 severe OSA patients with circular palatal collapse with clear latero-lateral prevalence. After 12 months post-operative, the authors recorded a significant reduction in AHI (36.9 ± 4.5/h vs 13.7 ± 4.5/h), reaching a successful outcome in 27 patients (84.4%) with no significant major complications. Two years later, Mantovani et al. [5] performed another clinical study on the Alianza BP technique in 17 moderate OSA patients with circular palatal collapse (caused by the combination of the anteroposterior and latero-lateral component) observing a statistically significant reduction in AHI (23.6 ± 3.9/h vs 5.1 ± 2.1/h) at the end of the 6-month follow-up. Vicini et al. [6] described a new intra-pharyngeal reconstruction procedure named Barbed Reposition Pharyngoplasty (BRP) carried out in 10 moderate-severe OSA patients with lateral palatal collapse as a part of multilevel surgery (3 trans oral robotic surgery (TORS) with tongue base reduction, 7 nasal and/or hyoid surgery) reporting after 6 months post-surgery a significant improvement in AHI (43.65 ± 26.83/h vs 13.57 ± 15.41/h $p = 0.007$). The same group confirmed the previous results in a small group of patients in 2017 [7] showing encouraging data (AHI pre 32.7/h vs AHI post 16.9/h). Furthermore, Montevecchi et al. [8] performed BRP as a single procedure or as a part of multilevel surgery (4 hyoid suspension, 2 TORS) in 111 OSA patients showing, after 6 months post-operatively, a significant improvement in AHI (33.4 ± 19.5/h vs 13.5 ± 10.3/h; $p < 0.001$). Madkikar et al. [9] have recorded a greater improvement in a subset of Indian population affected by severe OSA (AHI pre 40.6 and AHI post 10.2/h) without any major complications after BRP. Recently, Carrasco Llatas et al. [10] confirmed the encouraging results of Vicini's group, showing a significant decrease in AHI (29.1 ± 18.3/h vs 12.3 ± 12/h)

3 months after Modified BRP (MBRP) in 26 mild to severe OSA patients with latero-lateral collapse.

In 2018, Pianta et al. [11] updated Expansion Sphincter Pharyngoplasty (ESP) introduced by Pang. et al. [12] with the use of BS in 17 mild to severe OSA patients with oropharyngeal collapse observing a median post-operative AHI improvement of 7.8 events/h ($P < 0.01$) compared to preoperative with an overall success rate of 94.1%. Lastly, in the 2020, our group analysed the effects of Modular Barbed Anterior Pharyngoplasty (MBAPh) for snorers and mild-moderate OSA patients with anteroposterior collapse observing a statistically significant reduction in mean post-operative AHI values (18.66 ± 2.6/h vs 7.0 ± 4.2/h; $p = 0.0023$) at the end of the 6-month follow-up period. Currently, there are only three comparative studies on the BPs. Vicini et al. [13] conducted a Randomized Clinical Trial (RCT) comparing BRP with control group showing 6 months after surgery a significant reduction of AHI in the BRP group than control group. Barbieri et al. [14] compared BRP with BSP in 42 mild to moderate OSA patients observing comparable AHI values with a success rate of 86% and 100%, respectively. Finally, Babademez et al. [15] compared BRP with modified BRP in 34 mild to moderate OSA patients showing a significant reduction in AHI without no statistically relevant differences between the two groups. Currently, there are no studies on long-term results which specifically concern BPs. There is only one retrospective study on a heterogeneous group of pharyngoplasties (classic pharyngoplasties: UPPP and its variants and new pharyngoplasties: lateral pharyngoplasty, expansion pharyngoplasty, including RBP). The authors concluded that BRP such as the "new" pharyngoplasties seems to have more long-term stability than the "older" pharyngoplasties [16].

34.2.2 Barbed Pharyngoplasty for Snoring

In order to highlight the effect of BP on snoring, some authors evaluated, before and after surgery, the snoring Visual Analogue Scale (VAS). The first ones who used BS for snoring were Salamanca et al. in 2014 [17]. They performed Barbed Anterior Pharyngoplasty (BAP) on 24 patients with heavy snoring or with a mild OSA and stated that BAP "is an effective surgical procedure for the treatment of snoring and mild OSAS; the indication is represented by the anteroposterior pattern of palatal vibration/obstruction". They obtained a consistent reduction in the snoring VAS (from 9.2 to 2.9). Later, Mantovani et al. [5] using Alianza technique in 19 mild to moderate OSA patients with concentric collapse, showed a statistically significant reduction of the VAS scores (9.5 ± 0.7 vs 2.1 ± 1.7) after 6 months post-operative. A significant improvement in snoring VAS was also found by Elbassiouny [18] performing a modified barbed soft palatal posterior pillar webbing flap palatopharyngoplasty on 21 severe OSA patients with loud snoring (9.4 ± 1.6 vs 1.7 ± 3.2). Moreover, Carrasco Llatas et al. [10] recorded a significant improvement of snoring scale (3.3 ± 0.9 vs 1.9 ± 1.3, snoring scale from 1 to 5) after MBRP on 26 mild to severe OSA patients with latero-lateral collapse. Lastly, Babademez et al. [15] showed a greater reduction in snoring VAS in the modified BRP group than BRP group without statistically significant differences between the two groups (8 ± 1.5 vs 1.8 ± 0.8 vs 6.2 ± 1.9 vs 2.2 ± 1, respectively). Recently, Friedman et al. [19] proposed an innovative office elevoplasty procedure with BS performed under local anaesthesia in patients complaining of chronic disruptive snoring reaching a significant decrease of snoring VAS from 7.81 ± 1.59 to 5.77 ± 2.35 at 30 days, 4.48 ± 1.81 at 90 days, and 5.40 ± 2.28 at 180 days. However, larger samples are needed to confirm these interesting results.

34.3 Conclusions

There are many types of BP techniques that differ from each other for the BS passages made at the main surgical landmarks and for the management of the anterior and lateral pharyngeal walls (myoresective and non-myoresective techniques). BPs are safe, quick, and repeatable. There are no studies showing the superiority of one technique over the others even if the technique most described and with greatest results is the BRP introduced by Vicini. However, the best treatment of the lateral wall of the pharynx, in particular the palatopharyngeus muscle management remains a challenge [20]. BP could represent a safe tool in treating selected patients with snoring and OSA also in multilevel surgery with promising surgical success rates and significantly fewer complications. It can be considered suitable in the OSA multimodal strategy, a combination of different treatment modalities for OSA such as the association of upper airway surgery with conservative treatments. In the future, further randomized studies on a larger scale and with a long follow-up are needed to confirm these promising results.

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Barbed Pharyngoplasty Experience in Egypt

35

Ahmed Bahgat and Yassin Bahgat

35.1 Introduction

Recently, many surgical techniques for snoring and OSA were described to manage lateral pharyngeal wall collapse and to enlarge antero-supero-laterally the oropharyngeal isthmus, which are lateral pharyngoplasty [1], Z-palatoplasty [2], uvulopalatoplasty [3], expansion sphincter pharyngoplasty (ESP) [4], and relocation pharyngoplasty [5].

A new palatal procedure described by Mantovani et al. [6, 7] called Barbed Reposition Pharyngoplasty (BRP) was introduced. It includes using knotless bidirectional absorbable sutures to pull up the soft palate and widen the oropharyngeal inlet; the multiple lateral sustaining suture loops of BRP proved to be more stable than the single pulling tip suture of ESP, with no risk of tearing the muscle fibers losing the entire pulling force [8].

35.2 Historical Background

Uvulopalatopharyngoplasty (UPPP) and Laser-Assisted Uvuloplatoplasty (LAUP) were the most common surgical procedures at the soft palate level to manage OSA cases in Egypt [9]. Their primary mechanism was to shorten the soft palate by trimming its free edge. However, UPPP papers' analysis revealed its success rate is less than 50%, similar to CPAP effectiveness when considering patient adherence [10]. The concept of palatopharyngoplasty was shifted from destructive UPPP techniques to more reconstructive techniques [11]. Cahali et al. were first proposed lateral pharyngoplasty. He started to work on the lateral pharyngeal wall to widen the pharynx

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*, https://doi.org/10.1007/978-3-030-96169-5_35

and splint the soft palate rather than resection redundant tissues [1, 12]. Pang & Woodson described the expansion sphincter pharyngoplasty (ESP) to make the lateral pharyngoplasty less invasive but based on a similar idea [4]. A multicenter study of palate surgery's long-term complications in 217 patients concluded newer palatoplasty techniques had been shown to have fewer complications compared to old ones [13]. Vicini and colleagues introduced barbed reposition pharyngoplasty (BRP) to overcome ESP limits, including a single point of expansion in palatopharyngeus muscle towards a single point of suspension (pterygoid hamulus). Therefore, BRP included knotless sutures to make multiple expansion points in the palatopharyngeus muscles (multiple turns of sutures) towards the more rigid suspension structure (pterygomandibular raphe) [14]. BRP was proved safe and effective, either alone or as part of multilevel surgery, in a multicenter study [15]. The palatopharyngeus muscle side suture (as in BRP) was proved to be more effective than the muscle tip suture (as in ESP) in terms of postoperative flap stability [16]. BRP was also demonstrated to affect the results of multilevel surgery better than UPPP [17].

However, some problems encountered in the original BRP technique, such as

(a) suture extrusions with prolonged postoperative pain,
(b) long soft palates are not addressed regarding their length, and,
(c) residual snoring after surgery as the mid-palate is lax.

That is why we are performing the co-barbed pharyngoplasty “CO-BRP” technique in managing OSA cases in Egypt; Using coblation in palate preparation And using VLock sutures (different material from Stratafix) material in addressing the problems encountered in the original BRP technique.

35.3 Surgical Technique of CO-BRP

The operation was performed under general anesthesia through transoral intubation with an armored endotracheal tube with patients in the supine position and head in hyperextension. A Davis-Meyer mouth gag was used to expose the soft palate and pharynx, keeping the tongue in a central position. Surgical loupes (2.5× at 50 cm working distance) are recommended to be used for accurate visualization. The coblation settings were 7 for ablation mode and 3 for coagulation mode using cooled saline irrigation.

The coblation handpiece (EVac 70 Xtra, Smith & Nephew, UK) was used in tonsillectomy, palatopharyngeal muscle sectioning at the lower part with instant hemostasis, and ablation of supratonsillar fat in the lateral palatal space (as shown in Fig. 35.1) till the contact point (that is the point of contact of the soft palate to the posterior pharyngeal wall) [18].

The barbed sutures used are the V-Loc™ wound closure device (Medtronic, USA). Two ampoules are tied to make bidirectional sutures, and that tie is buried in the midline at the junction of the soft and hard palate.

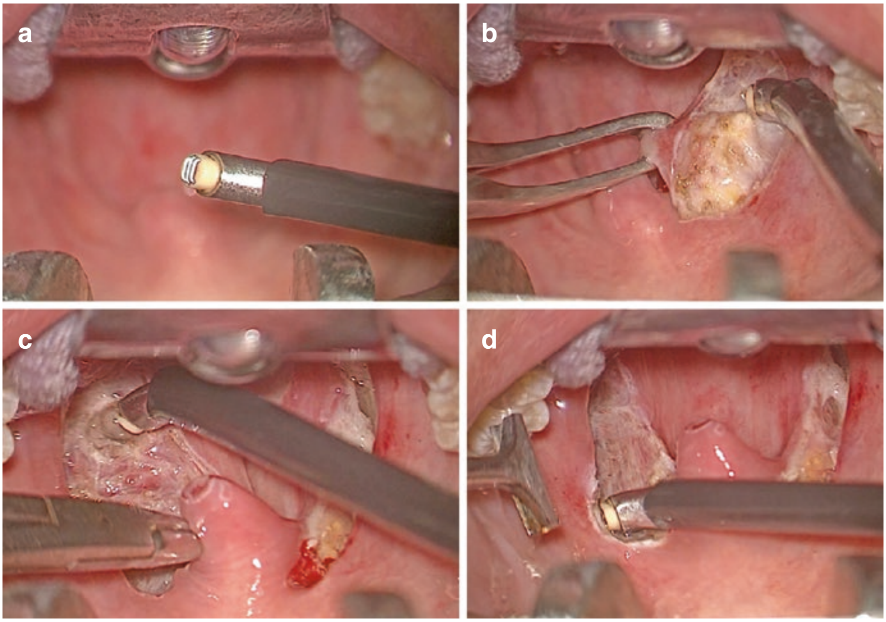

Fig. 35.1 (**a**) Coblation wand used (Evac 70 wand used for tonsillectomy) (**b**) Coblation tonsillectomy (**c**) Palatopharyngeus muscle weakening (**d**) Ablation of supratonsillar fat

The center of the palate is marked at the palatal spine. Also, the pterygomandibular raphe on both sides is located by digital palpation. One needle is introduced at the center point at the junction between the hard and soft palate, then passes laterally within the soft palate muscles, turning around the pterygomandibular raphe till it comes out at the most superior part of the raphe at one side. The needle is re-introduced at the same point of exit, passing around the pterygomandibular raphe till it comes out into the tonsillectomy bed at the upper pole, then through the upper third of the palatopharyngeus muscle and comes out close to the mucosa of the posterior pillar, not through it. Then, the needle is passed back through the tonsillectomy bed, and then this suture is suspended around the raphe again; very minimal traction is applied on the thread, and no knots are taken. Then this stitch is repeated at least three times between the raphe and the muscle till the lower pole of the muscle is suspended. Finally, each thread comes out at the raphe of the same side for locking of the stitches; a reverse suture is taken in the opposite direction; each suture is passed from one pterygomandibular raphe to the contralateral one to make midline stiffening of the soft palate to address snoring as well (as shown in Fig. 35.2). The thread is cut while pushing the tissue downward for more traction (Fig. 35.3).

If the uvula is too long, its tip is trimmed in a bevel fashion with nasal mucosa longer than oral. If the uvula is not long, a small island of the mucosa is removed from its anterior aspect, then coagulation of submucosal tissue is done by coblation; after suturing this mucosal gap, the uvula will bend forward, i.e., uvuloplasty.

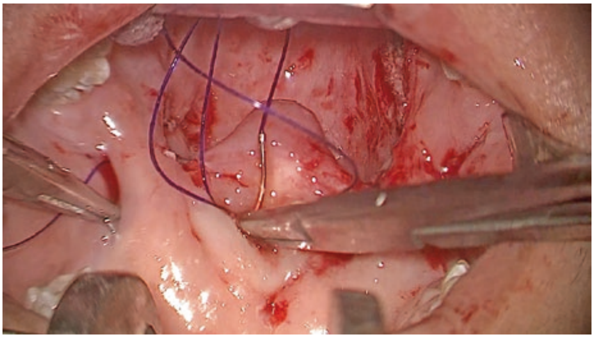

Fig. 35.2 (**a**) preoperative endoscopic retropalatal space (**b**) Postoperative endoscopic retropalatal space (**c**) preoperative oropharyngeal examination (**d**) postoperative oropharyngeal examination

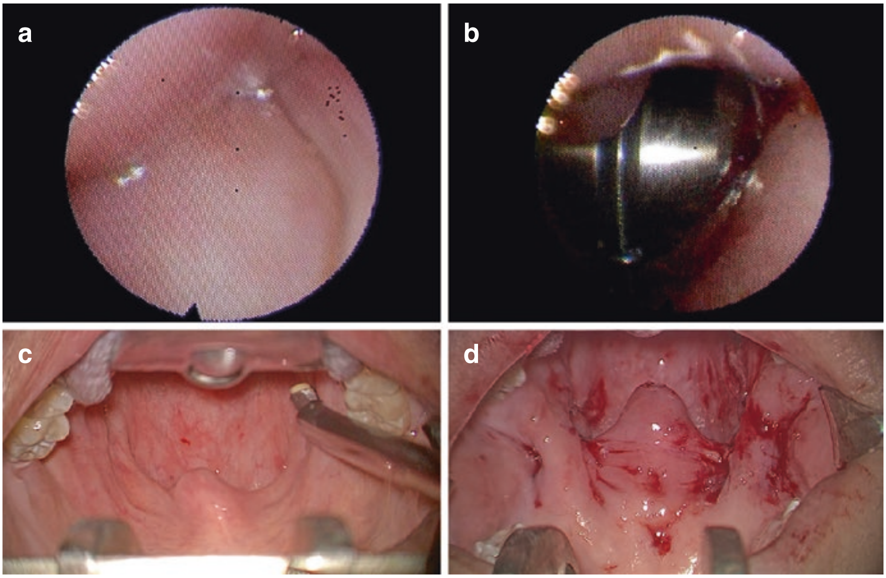

Fig. 35.3 The central barbed suture passing in the soft palate to address snoring in OSA patients

35.4 Postoperative Care

All patients receive positional therapy to elevate the head of the bed to 45° during hospitalization. A humidified oxygen mask is supplied in conjunction with continuous pulse oximetry during the first postoperative night. Systemic corticosteroids are given in the first 24 h following surgery. A perioperative prophylactic antibiotics are given pain control [intravenous ketorolac (30 mg, q6hr)]. Preoperative tracheostomy or postoperative intensive care unit stay is not a routine treatment procedure in those cases.

35.5 Outcome Measurement

Efficacy was defined by a comparison of pre- vs. postoperative changes in polygraphic parameters. Safety was defined by operative data (operation time, blood loss), recovery data [daily postoperative pain scores during hospitalization, visual analog scale 0–10, mean postoperative pain score during hospitalization (sum of daily pain score/hospitalization day), days for returning to a regular diet, and length of hospitalization], and complications (bleeding, taste disturbance, and airway compromise). The surgical response was defined as a reduction of AHI by more than 50% after surgery and postoperative AHI <20 events per hour [10].

35.6 Our Experience in Egypt

One hundred and fifty patients received co-barbed pharyngoplasty in the last five years. Fifty patients were excluded from the study due to being simple ten snorers, CO-BRP as part of multilevel surgery twenty two patients, and eighteen incomplete data. One hundred patients (70 males) underwent co-barbed pharyngoplasty in our study cases. Mean age was 40.87 ± 9.54 years, and mean BMI was 30.47 ± 3.56 kg/m^2. The large majority [80%] of participants had severe OSA, and other baselines and post-treatment data are shown in Table 35.1. The mean operation time is 22.73 ± 4.6 min. Blood loss of CO-BRP was <50 mL in all patients. Day 1

Table 35.1 The clinical characteristics and operative data of 100 patients undergoing co-barbed pharyngoplasty "CO-BRP" in Egypt

Sex • Males • Females	70 (70%) 30 (30%)
Age in years (mean ± SD)	40.87 ± 9.54
BMI in kg/m^2	30.47 ± 3.56
Preoperative DISE palatal collapse patterns	
• Anteroposterior (AP)	14 (14%)
• Lateral or transverse (T)	26 (26%)
• Circular (C)	60 (60%)
Tonsils size (according to Friedmann grades)	
• Grade 1	50 (50%)
• Grade 2	33 (33%)
• Grade 3	17 (17%)
Preoperative AHI	35.63 ± 10.57
Operative time (minutes)	22.73 ± 4.6
Postoperative pain (VAS)	3.63 ± 0.7
Postoperative AHI	17.07 ± 5.92
SD = standard deviation	

postoperative pain score was 2.8 ± 0.6. The average hospitalization duration was 1 to 2 days. The mean postoperative pain score during hospitalization was 3.63 ± 0.7. The time of returning to a regular diet was 16.6 ± 6.14 days. There were five postoperative bleeding cases; two of them were involving the tonsillar fossa re-treated by bipolar electrocautery in the operation theater. Temporarily decreased taste sensation was noted in twenty cases (20%), and only four patients (4%) reported taste disturbance at three months after surgery. All patients were extubated at the end of surgery with no postoperative re-intubation or tracheostomy. No patient required a feeding tube in the early postoperative period. There were no incidences of airway compromise, velopharyngeal insufficiency, or speech dysfunction during the recovery period.

Subjective improvement in snoring was reported in 90% of cases. Suture extrusion and wound dehiscence were reported in 16 cases (those were obese patients with higher BMI more than 32 as their pharyngeal muscles are thick and robust).

Repeat polygraphy was performed at least six months (range 6–9 months) following surgery and showed improvements in the AHI. Postoperative AHI < 15 was noted in 65 (65%) patients. The overall response rate was 76.66%. Postoperative AHI registered at six months after surgery was 17.06 ± 5.92 [preoperative AHI was 35.63 ± 10.57 ($P < 0.005$)].

The difference between CO-BRP rather than the original BRP technique is

(a) Using coblation in quick, bloodless tonsillectomy, in more extended ablation of supratonsillar fat, in lower palatopharyngeus muscle transaction.
(b) Using different barbed sutures and midline running sutures to address snoring.

Moreover, this technique is believed to be quick, short operative time, short exposure to anesthesia in those critically ill cases. The presence of cooled irrigation allowed less edema and less need to keep the patient intubated at the end of the surgery, early introduction of the oral diet with less postoperative morbidity [19, 20].

35.7 Conclusion

In Egypt, co-barbed pharyngoplasty seems to be effective in the surgical treatment of OSA among the Egyptian population. We believe that this technique offers sound, precise manipulation of the soft palate and pharynx in a safe and easy-to-learn procedure. The use of coblation in that technique allowed minimal pain by minimal tissue penetration and minimal thermal damage. It also permitted ablation of supratonsillar fat high up to the contact point to widen the lateral palatal space, shortening long soft palates, and allowed muscle-to-muscle suturing rather than muscle-to-fat suturing so better wound healing and fewer sutures extrusion. Different suture material was used (V-Loc™ wound closure device) with more barbs, so more stability of sutures in the soft palate that is always mobile during speech and swallowing. However, these results need to be confirmed in many cases with comparative studies with the original BRP.

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36 Barbed Pharyngoplasties: Experience in India

Sandeep Dachuri

36.1 Introduction

Obstructive sleep apnea (OSA) is a common problem in developing countries like India.

Even though snoring and sleep apnea have various treatment options like lifestyle modifications, Usage of CPAP (continuous positive airway pressure), mandibular advancement devices (MAD) and multiple varieties of surgeries, barbed reposition pharyngoplasty (BRP) has been proven as one of the most effective surgical option. BRP is a new palatal procedure using special suture material, described in 2015 by Prof Claudio Vicini [1] inspired by two different techniques by Dr. Montavani [2] and Dr. Hsueh-Yu Li [3].

36.2 Methodology

Here we describe our experience of performing barbed reposition pharyngoplasty in Indian patients at two tertiary care centers. Patients were carefully selected after proper assessment in the ENT outpatient department and undergoing polysomnography (sleep study). Only patients with moderate to severe OSA with BMI < 34 kg/m^2 were offered surgery. Preoperative drug induced sleep endoscopy was performed. A total of 23 patients underwent barbed reposition pharyngoplasty. The procedure is performed using the standard technique described by Prof Claudio Vicini [4] and is often combined with nasal surgery (septoplasty or turbinoplasty) in all the cases.

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_36

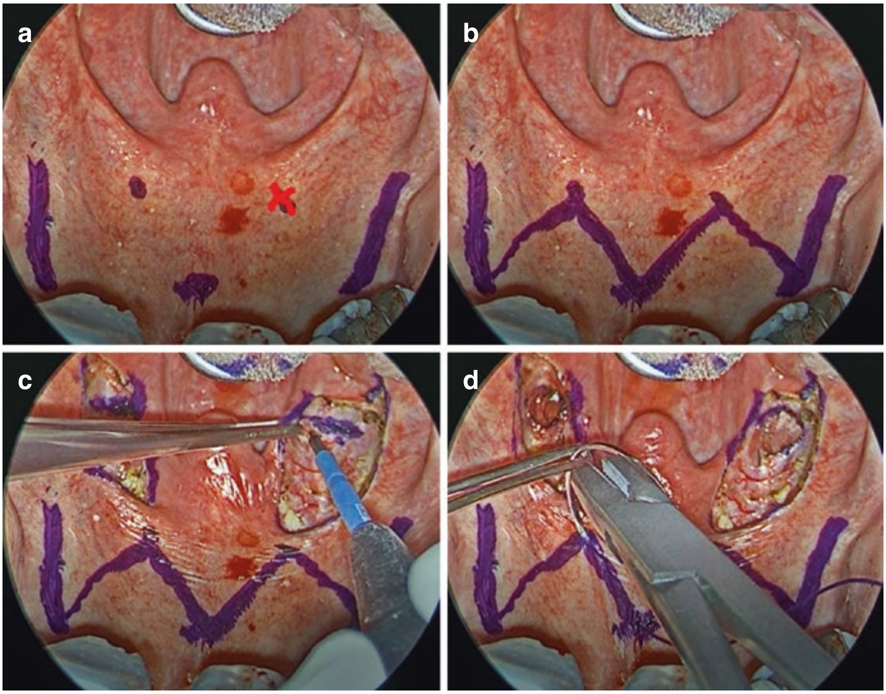

Fig. 36.1 (**a**) Marking of posterior nasal spine and bilateral pterygomandibular raphe and point X. (**b**) All the marked lines and dots are connected in a zig zag pattern. (**c**) Weakening of palatopharyngeus muscle done using monopolar cautery after tonsillectomy. (**d**) First bite taken from the posterior nasal spine to point X

After performing BRP, patients are extubated and kept under observation for 4 h in a postoperative ICU. They are kept on a liquid diet for 24 h and soft diet for 2 weeks (Figs. 36.1 and 36.2).

36.3 Results

All 23 patients who underwent BRP were males, age group ranging between 21 and 50 years. Among 23 patients, all were symptomatically improved after surgery but 2 patients were lost for follow-up. Among the rest of 21 patients, 3 patients refused to undergo postoperative sleep study. In long-term follow-up, 20 patients were symptomatically better and one patient complained of recurrence of snoring. After excluding 5 patients (2 lost for follow-up and 3 refusing postoperative sleep study), the mean preoperative AHI was 34.2 and the mean postoperative AHI was 13.8. Only one patient had recurrence in snoring and increase in AHI from 13 to 21 after the surgery.

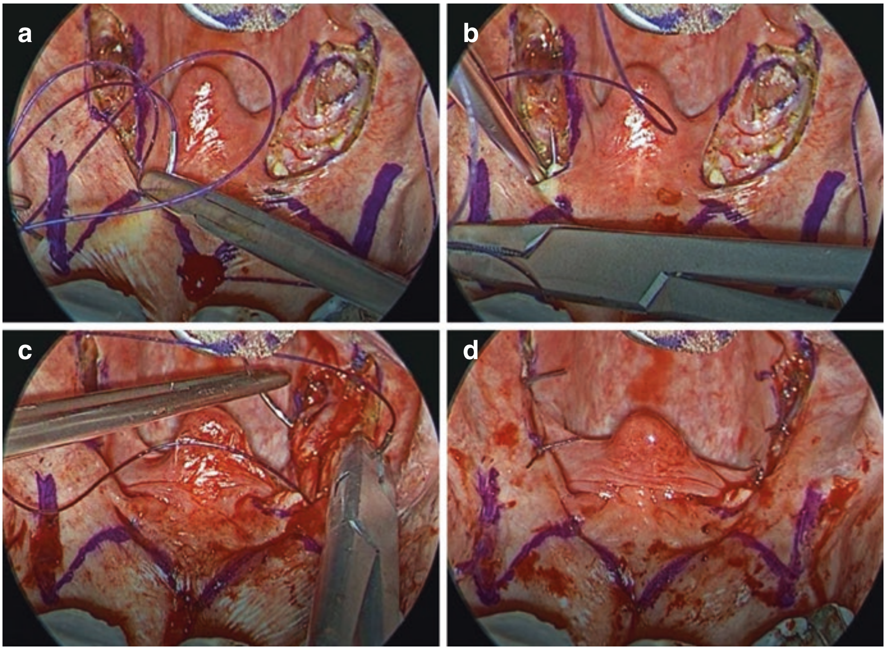

Fig. 36.2 (**a**) Second bite taken from point X and the needle comes out lateral to the pterygomandibular raphe. (**b**) From the lateral point of pterygomandibular raphe, needle is brought out through the upper pole of tonsillar fossa. (**c**) Bites taken through the bulk of palatopharyngeus muscle from lateral to medial direction sparing the mucosa. (**d**) Final appearance after the suture ends are cut

36.4 Discussion

The causes of OSA are multifactorial and the obstruction is usually multilevel. Soft palate is one of the most common sites of obstruction in these patients. Proper addressing of the soft palate during sleep apnea surgeries is the key to success in treating these patients surgically. In barbed reposition pharyngoplasty, the soft palate is pulled forward and laterally creating a better space rather than radical excision of the palatal structures. The key advantage is that barbed reposition pharyngoplasty has a very good success rate compared to other sleep apnea surgeries and can also be repeated if the primary surgery fails.

Challenges of practicing sleep surgery in developing countries:

1. A lot of patients are reluctant to visit a doctor for their snoring problem or OSA.
2. It is not easy to get sleep study/polysomnography in most of the smaller cities and towns.
3. Availability of flexible scopes is a big problem in developing countries unlike western countries and having a flexible scope is almost mandatory for proper assessment of these patients.

4. Lack of regular follow-ups by patients.
5. Expenditure of DISE is not covered by medical insurance companies.
6. Using CPAP is a huge stigma in some societies and it also adds to the lower compliance.
7. Repeating polysomnography is not easy in all patients due to limited financial resources.

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37 Barbed Pharyngoplasties Experience in Singapore

Khai Beng Chong and Song Tar Toh

37.1 Introduction

Singapore is a multi-ethnic country located in Southeast Asia. The three major ethnic groups are Chinese, Malay, and Indian, with a small minority of Eurasians and other ethnicities. Based on adult population screening using type 3 sleep study, the estimated prevalence of moderate to severe obstructive sleep apnea (OSA, with apnea: hypopnea index (AHI) ≥ 15) is 30.5% among Singaporean adults [1]. This is significantly higher than the estimated 10% prevalence among American adults noted in the Wisconsin Sleep Cohort Study [2].

In a retrospective study of 2160 Singaporean adults diagnosed with OSA (21.4% had mild OSA, 27.0% had moderate OSA, and 51.6% had severe OSA), only 751 (34.8%) agreed for continuous positive airway pressure (CPAP) therapy trial [3]. Two hundred eighty eight (13.3%) patients preferred surgery upfront, 291 (13.5%) patients chose adjunctive treatments (weight loss, positional therapy, dental appliance, intranasal steroid spray for allergic rhinitis), and 830 (38.4%) patients declined all treatment options [3]. Out of the 751 who had one month CPAP therapy trial, only 381 (50.7%) continued long-term CPAP therapy [3]. The same study also noted that CPAP compliance at one year was better for those who had successful one month CPAP therapy trial or previous upper airway surgery [3].

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*, https://doi.org/10.1007/978-3-030-96169-5_37

37.2 History of Pharyngoplasty in Singapore

As a significant number of OSA patients reject CPAP therapy or have poor long-term CPAP compliance, upper airway surgery has become an important alternative treatment option. We perform upper airway surgery with the aim for cure for suitable OSA patients. Details of patient selection criteria are covered in another chapter. Upper airway surgery is also done to help initiate or facilitate CPAP therapy for some patients, e.g., those with nasal obstruction secondary to nasal turbinates and adenotonsillar hypertrophy.

The traditional uvulopalatopharyngoplasty (UPPP) technique was first introduced by Ikematsu in 1964 [4] and later popularized by Fujita in 1981 [5]. UPPP became one of the most widely performed surgery for OSA worldwide, including Singapore. Since then, various modifications were made to the traditional UPPP technique.

Singapore's healthcare institutions regularly invite world renowned ear, nose and throat (ENT) experts to the country to share their expertise and new surgical techniques. Singaporean ENT surgeons also frequently visit other leading healthcare institutions in North America, Europe, and Asia for advanced fellowship training in sleep apnea surgery. Over the years, different pharyngoplasty techniques were introduced to Singapore. Relocation pharyngoplasty, lateral pharyngoplasty, and expansion sphincter pharyngoplasty were some of the more commonly performed pharyngoplasty techniques.

37.3 How Barbed Pharyngoplasty Started in Singapore

Mantovani and team were the first to use barbed sutures for pharyngoplasty, and introduced the "barbed Roman blinds" technique [6]. Since then, barbed sutures were used for several other pharyngoplasty techniques. Some of the older techniques were also modified to incorporate the use of barbed sutures. Based on the systematic review by Moffa et al., there were 5 published barbed pharyngoplasty techniques: barbed snore surgery, barbed reposition pharyngoplasty (BRP), barbed expansion sphincter pharyngoplasty, barbed suture suspension, and barbed soft palate posterior webbing flap pharyngoplasty [7].

Singapore was introduced to barbed sutures for upper airway surgery by Professor Claudio Vicini who first described the BRP technique [8]. A team of Singaporean ENT surgeons visited Morgagni-L. Pierantoni Hospital, Forli, Italy in 2015 to observe the surgical technique performed by Vicini himself. Two junior Singaporean ENT surgeons later became Professor Vicini's surgical fellows in Italy and had hands-on training in BRP surgery. Professor Vicini also came to Singapore twice as invited ENT expert and shared his technique and experience with many other Singaporean ENT surgeons. Currently, BRP is done at several public and private hospitals in Singapore as the surgical technique of choice for airway collapse at soft palate level.

37.4 Barbed Reposition Pharyngoplasty (BRP) Technique in Singapore

BRP is the main barbed pharyngoplasty technique performed in Singapore. The basic technique is based on Vicini's initial description of BRP in 2015, which involves the use of bidirectional, knotless barbed sutures to suspend the palatopharyngeal muscle to the pterygomandibular raphe [8]. Although not an essential assessment, drug induced sleep endoscopy (DISE) is commonly done before BRP. BRP is recommended for OSA patients with significant obstruction at the level of the velum.

Similar to Vicini's technique [8], we started with a bidirectional, polydioxanone monofilament, size 0 barbed suture with 36 mm taper point curved needle (brand name: Stratafix by Ethicon) for every pharyngoplasty. When compared with BRP for Italians, we noticed that BRP was more difficult for many Singaporean patients. Due to the difference in craniofacial structures, many Singaporeans of Chinese and Malay ethnicity have relatively small mouth and narrower oropharynx. Manipulation of a bidirectional 36 mm needle in a small cavity can be challenging especially for less experienced surgeons. We started using polydioxanone size 2–0 barbed suture with 26 mm taper point curved needle (brand name also Stratafix by Ethicon) for such patients to allow better manipulation of barbed sutures in small mouth and narrow oropharynx. Interrupted stitches using vicryl 3–0 suture with round body needle are often added to close and reinforce the mucosal gap between the palatopharyngeal muscle and anterior pillars.

BRP is effective in lateral widening of the soft palate. After completing BRP, some may still have persistent anteroposterior collapse of the uvula and distal soft palate. This is addressed by various techniques depending on surgeon's training and preference. Some surgeons prefer to trim the tip of a long uvula, leaving most of the rest of uvula intact. A transverse elliptical excision of soft palate mucosa anterosuperior to the uvula, followed by bipolar coagulation of the submucosal tissue and closure of the mucosal gap can also be done in the same setting to direct the uvula and distal soft palate more anteriorly (technique described by [8]). Complete excision of the uvula (uvulectomy) is rarely performed. At least one surgeon addresses the uvula and distal soft palate collapse by performing uvulopalatal flap (technique described by [9]) together with BRP.

BRP can be done as a single procedure for OSA or in combination with other upper airway procedures as part of multilevel surgery. The decision (single or multilevel surgery) is made based on either DISE or awake upper airway endoscopy findings. We often perform BRP with nasal surgery (such as septoplasty and inferior turbinoplasty), adenoidectomy, tongue base reduction and/or epiglottoplasty.

37.5 Future Research

Although systematic review of literature has shown overall positive outcomes for barbed pharyngoplasties [7], there is no publication on the results and complications of BRP in Singapore. The efficacy of BRP alone is also difficult to assess as it is often performed as part of multilevel upper airway surgery. This is an area for potential research in the future. A prospective, randomized controlled study on BRP for OSA will give us a better insight on the outcomes for different Asian ethnic groups in multi-ethnic Singapore.

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Barbed Pharyngoplasties Experience in Thailand

38

Chairat Neruntarat and Petcharat Saengthong

Obstructive sleep apnea (OSA) is a common disease in adults and around 1 billion patients on the globe are involved [1]. The prevalence of OSA and OSA with excessive daytime sleepiness in Thai adults is 11% and 4%, respectively. In addition, the prevalence of snoring is 24%. This reveals that OSA is a public concern in our country as in others [2]. OSA is described as partial or complete recurrent episodes of upper airway collapse with a decrease or complete cessation of the airflow. The pathophysiological traits or endo-types of OSA comprise a small and collapsible upper airway, lower dilator muscle reaction, reduced arousal threshold, and hypersensitive respiratory control system [3].

OSA is related to health concerns, including sleepiness, cardiovascular disease, cerebrovascular disease, metabolic disorder, car accident, cognitive impairment, work performance impairment, anxiety, and depression [4, 5]. Conservative treatments include weight control, exercise, alcohol and tobacco avoidance, position therapy, myofunctional therapy, different medications, oral appliances, surface electrical stimulation, and continuous positive airway pressure [6, 7]. Surgical treatment options are alternatives when conservative treatments fail by reducing the airway obstruction due to the excessive soft tissues of the pharynx. One study showed that twenty percent of Thai OSA patients underwent surgical treatment [8]. The success of surgical treatment of OSA depends on appropriate surgical procedures, which are determined by the anatomical and physiological conditions.

The surgical procedure for the palatal collapse in OSA is uvulopalatopharyngoplasty (UPPP) by removing the uvula and excessive tissue from the soft palate and

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_38

pharynx, which are common sites of obstruction [9]. After that, many palatal surgical procedures for OSA have been developed to reconstruct the pharyngeal walls and enlarge the velopharyngeal lumen. These procedures have lower postoperative complications and morbidities because of the reconstructive principles. In addition, many studies have been reported from our country in the treatment of OSA [8, 10, 11] as well as in the treatment of snoring [12, 13]. Palatal surgical procedures have changed throughout recent years from the classic UPPP to less invasive surgeries and barbed pharyngoplasties have been successfully reported [14, 15].

The barbed suture with knotless absorbable material is used for obtaining a suspension of the palatopharyngeal muscle in a lateral and anterior position for expansion of the lateral walls of the oropharynx. Multiple sutures enlarge the oropharyngeal isthmus laterally and reorganize anteriorly the lateral insertion of the soft palate to improve the retropalatal airway. These decrease AHI and improve surgical success rate when compared with UPPP and can be achieved successfully as single-level and multilevel surgeries [16, 17]. Studies have revealed that these procedures are safe and cost-effective options for patients with OSA in the long term [18, 19].

38.1 Preoperative Assessment

This includes history taking, sleep behavior, Epworth Sleepiness Scale, STOP-BANG questionnaire, GOAL questionnaire, snoring VAS, general examination, body mass index, otolaryngology examination, endoscopic evaluation, Muller maneuver, Fujita Classification, Mallampati Classification, Friedman Staging System, Tucker Woodson Method, cephalogram, routine laboratory study, polysomnography (attended or unattended), sleep study, and drug-induced sleep endoscopy.

38.2 Indication

Barbed pharyngoplasties are indicated in Thai patients who refuse or fail conservative treatment, or combined with other surgeries or therapies in the treatment of

1. Primary snoring.
2. Upper airway resistance syndrome.
3. Obstructive sleep apnea (oropharyngeal collapse: anteroposterior, lateral pharyngeal wall or concentric collapse type).

38.3 Contraindication

1. Severe comorbidities.
2. Contraindication for surgery.
3. Bleeding disorder.
4. Allergy to the suture material.

38.4 Surgical Procedures

Many otolaryngologists in Thailand perform bared pharyngoplasties including barbed reposition pharyngoplasty (BRP), barbed anterior palatoplasty, modified barbed reposition pharyngoplasty, and barbed suspension pharyngoplasty. In addition, we perform barbed palatal suspension (BPS), our technique in Thailand. (Table 38.1).

38.4.1 Barbed Palatal Suspension

Barbed palatal suspension could be performed under local anesthesia for snoring, upper airway resistance syndrome, and mild OSA. This could be conducted as an adjunctive procedure to other barbed pharyngoplasties under general anesthesia. The barbed suture is used instead of the permanent suture as in the palatal suspension for OSA [20]. The suture is entered into the periosteum and the fibromuscular layer of the soft palate at PNS and inserted along the soft palate in the right side to exit 2 cm from the base of the uvula. The suture is inserted horizontally through the base of the uvula to the opposite side. It is then conducted into the PNS, symmetrically, and pulled to move the soft palate forward. A repeated procedure can be performed as a double loop palatal suspension or more to enhance the forward drive of the soft palate. (Fig. 38.1).

38.4.2 Barbed Reposition Pharyngoplasty

Tonsillectomy is performed while the palatoglossus (PGM) and palatopharyngeus (PPM) muscles are preserved. The posterior nasal spine (PNS) and the pterygomandibular raphe (PMR) are identified. Barbed suture is advanced to the soft palate at the PNS and delivered in the muscular layer and is inserted in one side to the PMR. The needle is passed through the PPM and then the suture is suspended around the PMR. The suture is repeated between the PMR and the PPM to further widening of the pharynx. The same procedure is performed on the other side. (Fig. 38.2a).

Table 38.1 Barbed pharyngoplasties experience in Thailand

Barbed pharyngoplasties	Thailand	Others
Barbed reposition pharyngoplasty	+	+
Barbed suspension pharyngoplasty	+	+
Modified barbed reposition pharyngoplasty	+	+
Barbed anterior palatoplasty	+	+
Barbed expansion sphincter pharyngoplasty	–	+
Modified soft palate posterior pillar webbing flap palatopharyngoplasty	–	+
Barbed palatal suspension	+	–

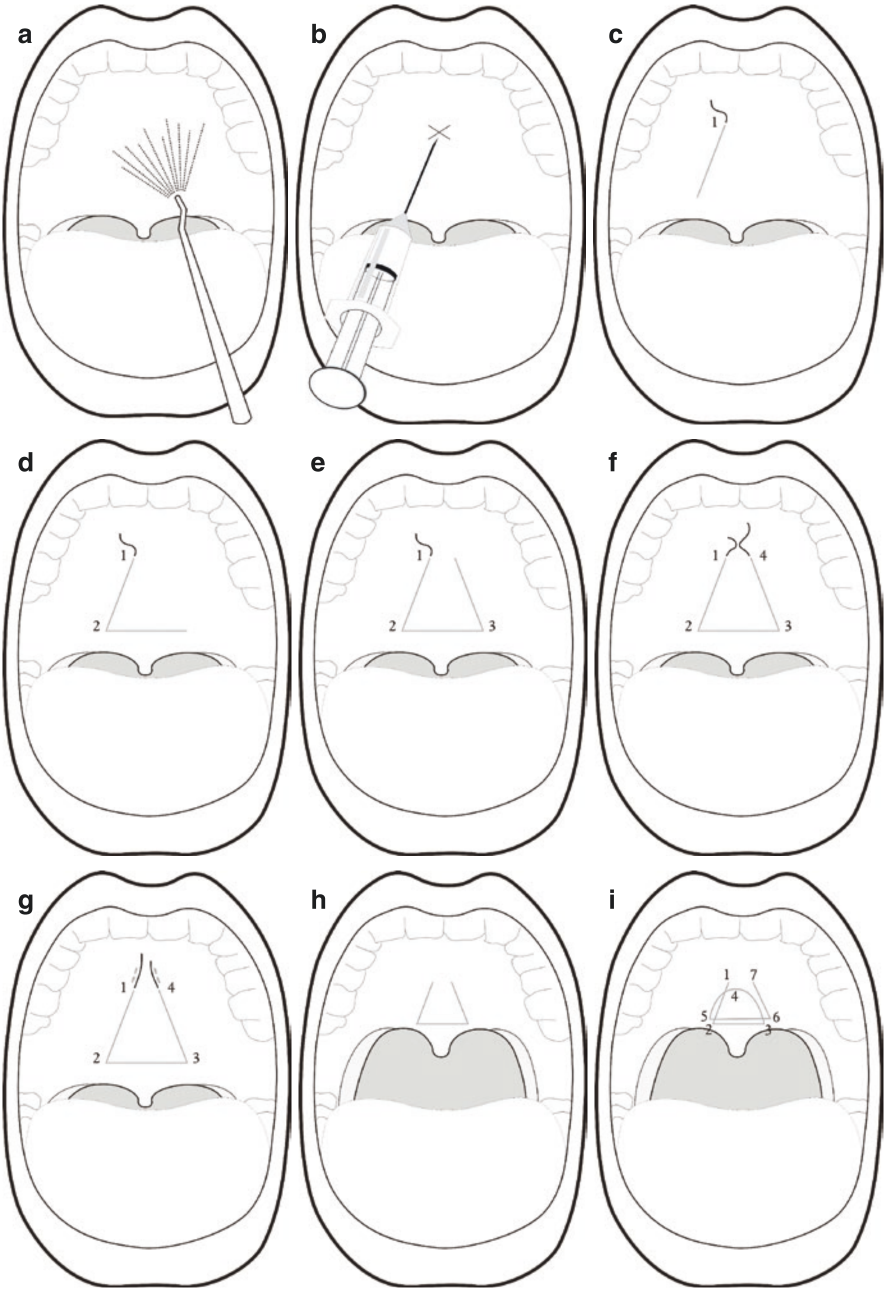

Fig. 38.1 (**a**, **b**) Local anesthesia with spray and an injection is applied. (**c**) The suture is entered the soft palate on the right side. (**d**) It runs horizontally through the base of the uvula. (**e**–**h**) It is conducted into the PNS and pulled to move the soft palate forward. (**i**) A repeated procedure can be performed as a double loop palatal suspension

38.4.3 Barbed Anterior Palatoplasty

A mucosal palatal flap in the central part of the soft palate is removed. A needle is entered into the soft palate at the right pterygoid hamulus. The underlying muscles are tightened with continuous suture. It is stitched a few times in the muscular plane and coupled the left edge of the wound to the left hamulus. The submucosal suture is achieved at the right hamulus, joined the lower edge of the wound to the aponeurosis, and rose near the left hamulus. (Fig. 38.2b).

38.4.4 Modified Barbed Reposition Pharyngoplasty

Tonsillectomy is performed and the inferior portion of PPM is moderately released. A barbed suture is entered at the PNS and then delivered around the PMR. It is passed to the PPM and then back to the PMR again a few times. The suture is inserted horizontally through the base of the uvula to the opposite side. The same procedure is performed on the other side and the suture was returned to the center point. (Fig. 38.2c).

38.4.5 Barbed Suspension Pharyngoplasty

Tonsillectomy is performed and the PPM is preserved. The suture is entered the soft palate at the level of the PNS and inserted towards the upper part of the tonsillectomy bed with two passages restoring the needle close to the tip of the exit. Several stitches are employed around the upper portion of the PPM, attaching it to the anterior pillar. A suspension suture is conducted into the PMR and pulling. Added stitches are made in the palatal muscles through the base of the uvula to the contralateral PMR and going back to the ipsilateral raphe. (Figs. 38.2d and 38.3).

38.5 Results

Barbed pharyngoplasties reveal subjective and objective improvements for OSA which are comparable to other palatal surgeries with a median success rate of 83% ranging from 60% to 95% [21–33]. There is a comparison study between BRP and expansion sphincter pharyngoplasty (ESP). A meta-analysis demonstrates similar outcomes between BRP and ESP in terms of AHI reduction, postoperative AHI and ESS, ODI reduction, postoperative pain, hospital stay, time to oral diet, and success rate. The reduction in AHI in the BRP and ESP is 74% and 60%, respectively. The success rate in the BRP and ESP is 85% and 80%, respectively. Additionally, BRP takes less operative time than ESP [34]. Our results are encouraging and in agreement with others.

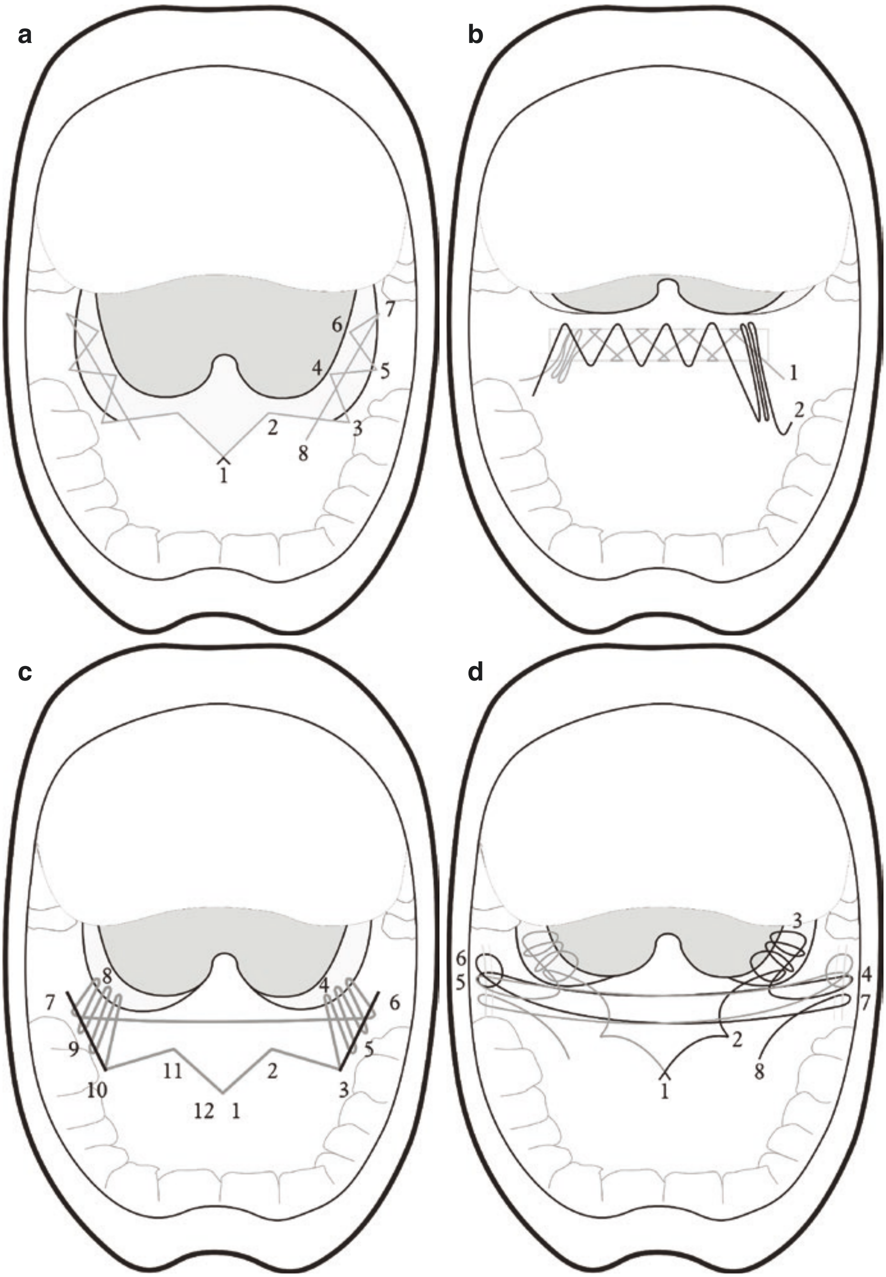

Fig. 38.2 (**a**) Barbed reposition pharyngoplasty, (**b**) Barbed anterior palatoplasty, (**c**) Modified barbed reposition pharyngoplasty, (**d**) Barbed suspension pharyngoplasty

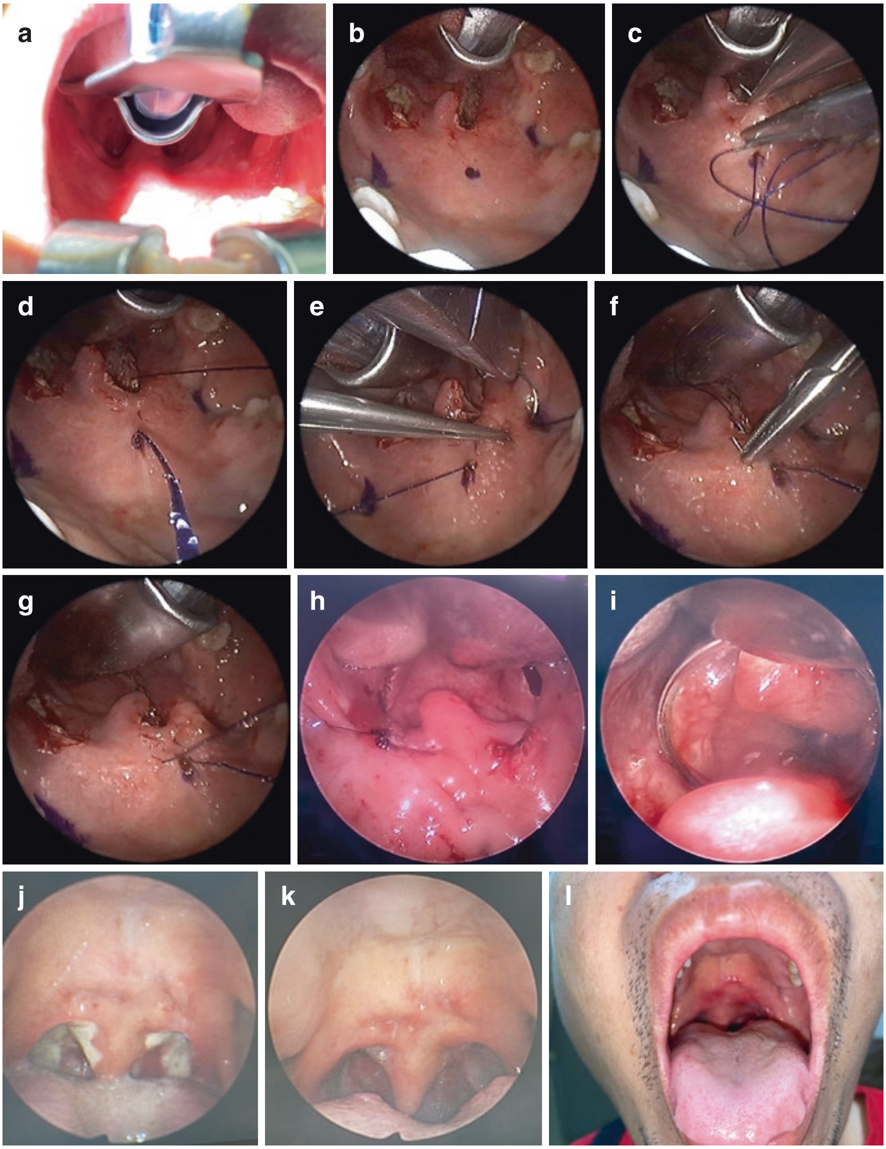

Fig. 38.3 (**a**) Preoperative, (**b**) Tonsillectomy is done, (**c**–**g**) Barbed suspension pharyngoplasty is performed, (**h**) Postoperative, (**i**) Enlarged oropharyngeal airway, (**j**) 1 week postoperative, (**k**) 2 weeks postoperative, (**l**) 6 months postoperative

38.6 Complications

Complications including broken needle and suture rupture are confronted during the intraoperative period. In a few cases, the suture is partially extruded for a short segment because of the retraction of the tissue. The protruding piece is cut without disturbing the outcomes. In addition, a few patients complain of transient dysphagia, dry throat, and throat phlegm. Bleeding, taste disturbance, infection, fistula, palatal abscess, pharyngoplasty dehiscence, velopharyngeal insufficiency, voice change, and airway obstruction are not encountered in our patients.

38.7 Barbed Suture

Various sutures are available to perform the procedure such as QUILL® knotless tissue closure device, polydioxanone absorbable thread, V-LocTM 180, and Stratafix absorbable polydioxanone. The third one is available in Thailand as unidirectional or bidirectional suture, size 0 and 2-0, in addition, the cost is 1200 baht (40 USD) which is a reasonable cost in Thailand.

38.8 Single-Level or Multilevel Surgery

These procedures can be conducted as single-level or multilevel surgeries for treating simultaneously multiple obstructions in the same session. In cases of multilevel obstruction, we perform barbed pharyngoplasties with septoplasty, turbinoplasty, or radiofrequency reduction of the tongue without serious complications.

38.9 Conclusion

Barbed pharyngoplasties are safe, fast, simple, cost-effective procedures for our patients as in other countries. We add barbed palatal suspension as an adjunct procedure to barbed pharyngoplasties in the treatment of snoring and OSA. Multicenter co-operation and long-term follow-up are necessary to further reveal the efficacy of these procedures.

Acknowledgments

Conflict of Interest The authors declare that they have no competing interests.

Funding No funding was received.

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Barbed Pharyngoplasties Experience in Spain

39

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39.1 Introduction

In Spain, use of barbed sutures to perform pharyngoplasty for obstructive sleep apnea (OSA) patients started after Prof. Claudio Vicini was invited to the 65th National Congress of the Spanish ear, nose and throat (ENT) society

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_39

(SEORL-PFC). There he shared their initial experience with the barbed suture and demonstrated the Barbed Reposition Pharyngoplasty (BRP) technique on video. Months afterwards, the first article on the BRP technique with their preliminary results was published [1].

Currently, the only other group to publish surgical results post barbed pharyngoplasty is from Hospital Universitario Dr. Peset in Valencia, therefore, it is not possible to know if these results can be extrapolated to other hospitals.

A survey in Spain identifying ENT experience with barbed suture for OSA surgery was launched, unfortunately yielding few results due to very low participation. Only 62 people answered the survey, of whom 34 performed any type of pharyngoplasty and 17 used barbed sutures routinely to perform them. No more useful data can be obtained from this survey due to the small sample size, not representing ENT experience in Spain. Albeit can be seen that barbed sutures popularity is spreading amongst the Spanish ENT due to advantages including reduction of surgical time and increased pharyngeal stability.

A statistical analysis comparing these two centers is possible, thanks to the transfer of the retrospective data from the ENT department of the Ospedale Morgagni-Pierantoni from Forlí. It will be possible to uncover whether differences in our barbed techniques offer any advantage. Essentially, both techniques differ in the higher number of loops that are performed in Valencia in the lateral pharyngeal walls (LPW) and the soft palate. Nevertheless, for a better understanding of the two techniques, Chapters 14 and 26 should be read.

39.2 Materials and Methods

This is a retrospective study of all the OSA patients operated with barbed sutures in Ospedale Morgagni-Pierantoni in Forlí, Italy and the ones operated in Hospital Universitario Dr. Peset in Valencia.

Inclusion criteria were adult patients with sleep study pre and 3 to 6 months after surgery.

Data analyzed was age, body mass index (BMI), tonsillar grade according to the Friedman scale, Epworth sleepiness scale (ESS), nasal or multilevel surgery performed in addition to the barbed pharyngoplasty and the data from the pre- and postoperative sleep studies.

For the statistical study, the program Stata v12 was used. Continuous variables were compared with t-paired test between pre and post in each center and with t test between centers. $p < 0.05$ was considered significant. In addition, a regression model with ANCOVA was constructed with the significant variables comparing the postoperative results between centers.

Several definitions of success were considered according to the postoperative AHI obtained (<5, <10, <15 and the classical Sher's definition). Moreover, the difference pre and post (delta) (calculated AHI pre-AHI post) and the relative delta (AHI pre -AHI post/AHIpre x100) were obtained.

39.3 Results

The final sample size was 138 patients (70 from Forlí and 68 from Valencia).

Patients from Forlí were older than the ones from Valencia, nevertheless there were no significant differences in the mean BMI, ESS, or preoperative sleep parameters (Table 39.1). In both series, there was a significant improvement of the OSA patients with significant reductions in the respiratory events not related to a BMI reduction. When both series were compared, the patients from Valencia had better outcomes in general.

According to the different success rates, in Valencia the results were better as can be observed in Table 39.2.

We compared the proportion of nasal or multilevel surgeries performed in both centers to explain this difference in success. There were no differences in the number of tonsillectomies, but there were differences in the number of nasal surgeries

Table 39.1 Main variables evaluated before and after BRP by centers

	PRE Forlí *N* = 70	POST Forlí *N* = 70	*P* value	PRE Valencia *N* = 68	POST Valencia *N* = 68	*P* value
AHI	39.05 (19.19)	25.05 # (21.22)	0.00	36.32 (24.42)	13.52 # (14.22)	0.00
ODI	33.91 (17.74)	22.99 # (20.05)	0.00	34.54 (22.4)	15.19 # (16.36)	0.00
T 90	13.45 (17.47)	14.23 (22.85)	0.57	15.56 (20.76)	7.09 (10.82)	0.04
EPWORTH	9.30 (5.4)	8.18 # (5.87)	0.24	9.16 (5.25)	5 # (2.89)	0.00
BMI	27.48 (3.04)	27.19 (3.26)	0.17	28.37 (4.40)	28.58 (4.45)	0.79
AGE	55.09 # (11.47)			41.29 # (11.64)		

(): standard deviation, AHI: apnea-hypopnea index, ODI: oxygen desaturation index, T90: time spent with an oxygen saturation lower than 90%, BMI: body mass index
Statistically significant difference ($p < 0.05$) with respect to the same variable in the other center

Table 39.2 Different success criteria by centers

	Success 5 AIH < 5	Success 10 AIH < 10	Success 15 AIH < 15	Sher success	Mean delta AHI	Mean relative delta AHI
Forlí	14.29% #	30% #	42.86% #	44.29% #	13.36 # (21.3)	28.04 # (69.09)
Valencia	38.24% #	52.94% #	66.17% #	60.29% #	22.8 # (25.05)	51.02 # (50.54)

Delta AHI: pre-surgery AHI - post-surgery AHI
Relative Delta AHI: pre-surgery AHI—post-surgery AHI/pre-surgery AHI X 100
Statistically significant difference ($p < 0.05$) with respect to the same variable in the other center

and multilevel surgeries performed. At first glance, it seems that the Forlí patients needed more accompanying surgeries (Table 39.3).

The proportion of the different tonsil grades were compared and in Valencia there was a higher proportion tonsillar hypertrophy (48% versus 17%), a statistically relevant difference in distribution, which could explain the better results obtained (Table 39.4).

Therefore, the relative AHI delta was compared for each tonsillar grade. Except in the patients with tonsils grade 1, the relative delta was higher in the Valencia group (Table 39.5).

A regression model was performed with ANCOVA, showing that the results in Valencia were 11.41 e/h better (Table 39.6); after adjusting the model, this difference was reduced but still was significant (Table 39.7).

Table 39.3 Distribution of accompanying surgeries by centers

	Tonsillectomy	Nasal Surgery	Multilevel surgery
Forlí	82.76%	71.43%	50%
Valencia	86.76%	45.59%	25%

Table 39.4 Distribution of tonsil grade by centers

	Grade 0 (N)	Grade 1 (N)	Grade 2 (N)	Grade 3 (N)	Grade 4 (N)
Forlí	17.14% (12)	30% (21)	35.71% (25)	17.4% (12)	0% (0)
Valencia	8.82% (6)	19.12% (13)	23.53% (16)	45.59% (31)	2.94% (2)

Statistically different distribution $p = 0.003$

Table 39.5 Obtained Relative AHI Delta by tonsil grade and centers

	G 0	G 1	G 2	G 3	G 4
Forlí	−34.52 (125.66)	50.97 (34.42)	39.06 (44.79)	27.53 (45.35)	–
Valencia	27.17 (66.09)	27.35 (42.02)	59.34 (26.91)	58.13 (57.49)	99.53 (0.66)

Table 39.6 ANCOVA model comparing postoperative AHI. Valencia was the reference center

AHI post	Coef.	Std. error	t	$P > \|t\|$	[95% Conf. Interval]
Forlí	11.41	2.92	3.91	0.00	5.64–17.18
AHI pre	0.28	0.07	4.19	0.00	0.15–0.41
Cons	−8.07	5.14	−1.57	0.12	−18.24 - 2.09

Table 39.7 ANCOVA model including the significant variables. Valencia was the reference center

AHI post	Coef.	Std. Error	t	$P > \|t\|$	[95% Conf. Interval]
Forlí	5.84	3.64	1.61	0.11	−1.35 to 13.04
AHI pre	0.30	0.07	4.32	0.00	0.16–0.44
Tonsil grade	−3.34	1.51	−2.22	0.03	−6.33 to 0.36
Age	0.26	0.13	1.99	0.05	0.01–0.53
BMI	0.43	0.42	1.01	0.31	−0.41 to 1.27
Cons	−19.076	14.47	−1.32	0.19	−47.71 to 9.56

39.4 Discussion

The use of barbed sutures in Spain is spreading amongst ENT surgeons that perform pharyngoplasties, and nowadays is the preferred type of suture in 17 of the 34 centers that answered the survey.

Apparently, the number of loops performed in the LPW and the soft palate may help to improve the surgical success rates. The study performed by Barbieri et al. [2] in which an increase of surgical rate was obtained adding a raphe-to-raphe suture in the soft palate to their previous technique supports this theory.

Nevertheless, this initial appreciation must be tested in future prospective studies because in Valencia's group there was a higher proportion of patients with tonsillar hypertrophy that may explain this difference. Moreover, the higher number of multilevel and nasal surgeries performed in Forlí may indicate a selection bias, being the Forlí population more complex, therefore with a lower success rate from the start.

In addition, the data from the drug-induced sleep endoscopy (DISE) previous to surgery was not available for all the patients, so it is impossible to know if there were differences in collapse types in both centers. It is possible that the group from Forlí had a higher incidence of multilevel or velum complete concentric collapse, both known factors associated to lower success rates [3–5].

Unfortunately, due to the retrospective nature of this study, neither the Friedman Palate Position, nor the Modified Mallampati Index is known, therefore the success rates cannot be compared with previous series and the comparability between our series according to this issue is uncertain. Likewise, the objective tonsil volume measured after tonsillectomy is missing. As was pointed out by Sundman and Friberg [6], even the tonsil size measured with the Friedman scale does not have a high concordance amongst different explorers in the same center, this low concordance could be also low between our centers, despite the fact that both centers have experience doctors dedicated to OSA patients. The objective tonsil volume after histopathologic analysis could have resolved this limitation.

In addition, the Forlí group was older than the Valencia one, which could also be part of the better results in Valencia.

In conclusion, performing a higher number of loops in the LPW and soft palate may be responsible for the better outcomes in the Valencia's postoperative barbed pharyngoplasty OSA patients. Nevertheless, all the limitations mentioned before may explain these seemingly superior results and the differences presented may be biased and not reflect differences in the surgical technique, therefore this hypothesis must be confirmed in future prospective studies.

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40 Barbed Pharyngoplasty Experience in Brazil

H. S. S. Nunes and J. A. Pinto

40.1 Introduction

Currently, the uvulopalatopharyngoplasty (UPPP) remains the most common surgical procedure for OSAS alone or in combination with adjunctive multilevel procedures. Weaver [1] in a multicenter study demonstrated that UPPP improves quality of life and mitigates sleep apnea symptoms in patients with obstructive sleep apnea.

Multiple UPPP techniques shifting the concept of aggressive palate resection to palatal reconstructive surgery and improving function by changing its shape have been described.

While traditional techniques simply remove tissue, these new procedures involve reconstruction of the upper pharyngeal airway tissues, modifying structural abnormalities and improving form and function [2].

Barbed suture is an innovative technology that is here to stay. With the advent of polypropylene barbed sutures, the capacity of sutures to withstand loads has greatly increased. The first researcher to mention the concept of barbed sutures was Alcamo in 1964, followed by Fukuda in 1984, and Ruff in 1994 [3]. These pioneers used the barbed sutures to close wounds without the need for knots for general surgery procedure [4].

In 2008, Hur proposed a sling snoreplasty technique in an OSAS patient to “shorten, conglomerate, and tense” the redundant soft tissues of the soft palate by means of the trans-mucosal introduction of permanent threads through the fibromuscular plane of the soft palate. Mantovani introduces velo-uvulo-pharyngeal lift (VUPL) or “Roman blinds” technique, which not only lifts and stiffens the velo-uvular complex, but also widens the mesopharyngeal space [5].

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_40

The first and only publication concerning this suture in Brazilian Otorhilaryngology Journal was by Tavares et al., relating this kind of suture to facial lifting [4]. So far no records of a Brazilian experience with barbed pharyngoplasty technique have been reported; this is a pioneer project in our country.

We started this technique in 2018 after spending an enlightening time at Morgagni Pierantoni Hospital, Forlì, Italy, with Professor Vicini and his amazing team. They shared their experience using barbed suture and we started the technique in São Paulo, SP, Brazil.

We performed our first case in July 2018.

As it is known, barbed suture is a technology, rather than a technique. Our experience with barbed pharyngoplasty consists of adapting lateral-expansive pharyngoplasty technique with barbed technology.

To obtain better palatal expansion in patients with retropalatal and laterolateral collapse, we proposed the combined use of two techniques, lateral and expansion pharyngoplasty.

Based on the reconstructive surgical concept of the upper airway [2], lateral-expansive pharyngoplasty is a procedure intended to expand the pharyngeal space, addressing the antero-posterior and lateral retropalatal collapse.

Lateral-expansive pharyngoplasty consists of bilateral tonsillectomy, dissection, and section of the upper pharyngeal constrictor muscle (Fig. 40.1); and after identification and elevation of the palatopharyngeal muscle, the lower part section is performed (Fig. 40.2) [6]. The first step in using barbed suture is to mark the points of tension of the palate: posterior nasal spine, supra tonsillectomy bed point, and pterygomandibular raphe bilaterally [7]. We used a single barbed suture, bidirectional polydioxanone absorbable monofilament, size 0, with or without transition zone in the middle (V-loc® or Stratafix®). One needle was introduced at the center point then passed laterally within the palate to a superior tonsillectomy bed point and then rotated around the pterygomandibular raphe until it

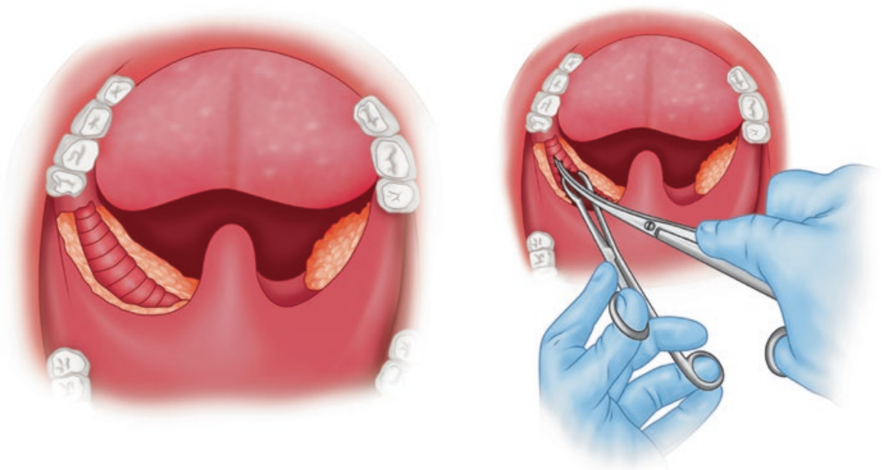

Fig. 40.1 Bilateral tonsillectomy, dissection, and section of the upper pharyngeal constrictor muscle

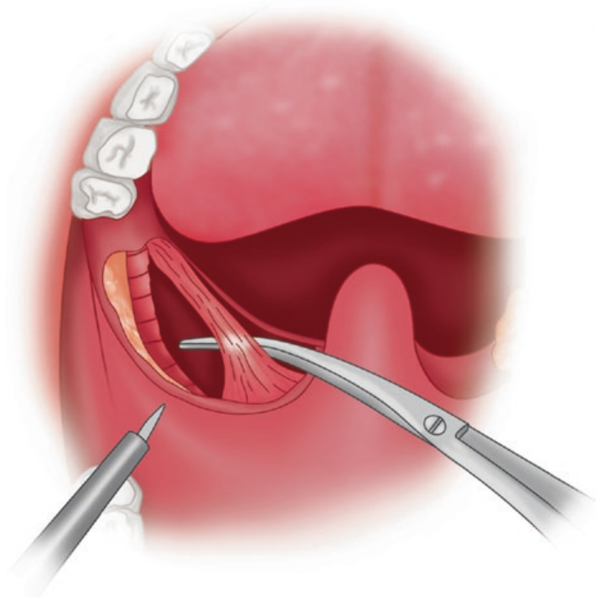

Fig. 40.2 Identification and elevation of the palatopharyngeal muscle, the lower part section is performed

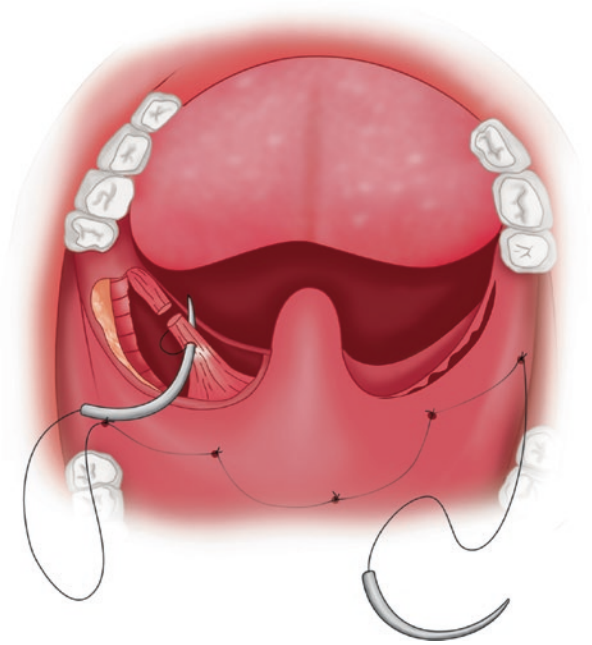

Fig. 40.3 One needle was introduced at the posterior nasal spine point then passed laterally within the palate to a superior tonsillectomy bed point, rotated around the pterygomandibular raphe. The needle was reintroduced close to the exit point, until it came out in the tonsillectomy bed, then to the uppermost part of the palatopharyngeal muscle

came out at the uppermost raphe (Fig. 40.3); the wire was pulled until it locked in the central transition zone, which is a free zone between the two directions of the wire .The needle was reintroduced close to the exit point, passing around the pterygomandibular raphe until it came out in the tonsillectomy bed, then to the

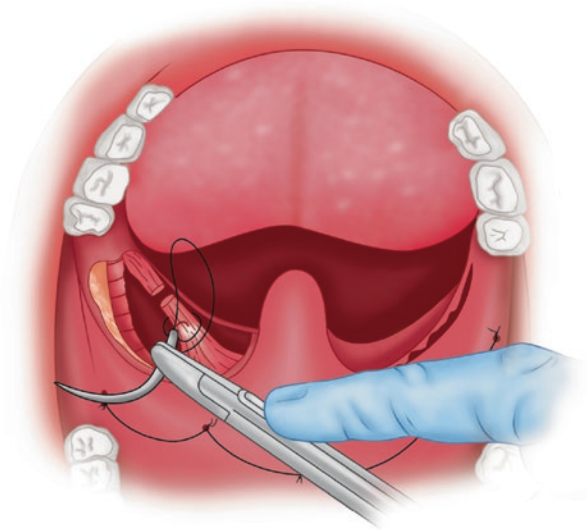

Fig. 40.4 The needle was passed back through the tonsillectomy bed and then this suture was suspended again around the raphe

uppermost part of the palatopharyngeal muscle and came out close to the mucosa of the posterior pillar, and not through it. Then, again the needle was passed back through the tonsillectomy bed and then this suture was suspended again around the raphe; a gentle pull was then applied only to the wire and no knots were made (Fig. 40.4). This led to a stable repositioning of the posterior pillar to a more lateral and anterior location, without any knots, so this point was repeated as many times as necessary. The opposite side underwent the same procedure. Finally, each thread came out of the raphe on the same side, and then the thread was cut while the tissue was pulled down for greater traction.

Note that instead of fixing the palatopharyngeal muscle near the hamulus of the pterygoid bone like in original lateral-expansion pharyngoplasty [6], we sutured it in the pterygomandibular raphe.

The patient selection was the first important point. We performed lateral-expansive barbed pharyngoplasty in patients who had an anterior-posterior palate collapse or circular collapse confirmed by DISE. Other inclusion criteria were primary snore, mild and moderate OSAS.

Our postoperative results analysis is still ongoing. Due to the Coronavirus Pandemic [8], many surgeries were suspended and there was a significant delay during the years 2020 and 2021.

40.2 Results

From July 2018 to May 2021, our group selected 15 cases. Considering movement restrictions and limited elective surgeries in 2020 and 2021, we believe this is a good number. The mean age was 33.4 years, the mean AHI was 20.41. All the

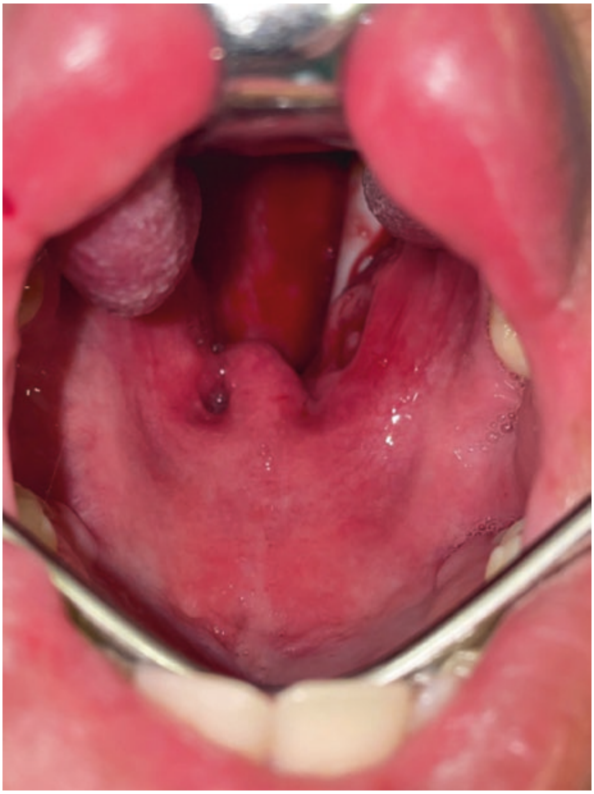

Fig. 40.5 Preoperative findings of the palate of a patient with an AHI of 15

patients performed multilevel surgery. A total of 20% of patients were submitted to glossectomy with coblation, septoplasty, turbinectomy, and barbed pharyngoplasty, and 80% performed septoplasty, turbinectomy, and barbed pharyngoplasty.

Since it is a recent technique and due to the restriction imposed by the pandemic concerning surgeries, we were not able to collect the objective result of postoperative polysomnography from all patients. However, the subjective result presents good prospects and improved quality of life in these patients. Partial results show similar outcomes to the technique lateral-expansion pharyngoplasty without barbed suture. Six months after the surgery, patients who underwent the combined lateral-expansion barbed pharyngoplasty approach achieved significant reduction in excessive daytime sleepiness and snoring. We noticed a decrease in surgical time compared to the technique without barbed suture (Figs. 40.5 and 40.6).

From our experience, we agree with Iannella et al. that barbed suture holding properties of tissue are superior to Vicryl's, enduring more strength when compared to expansion sphincter pharyngoplasty and lateral-expansion pharyngoplasty [9].

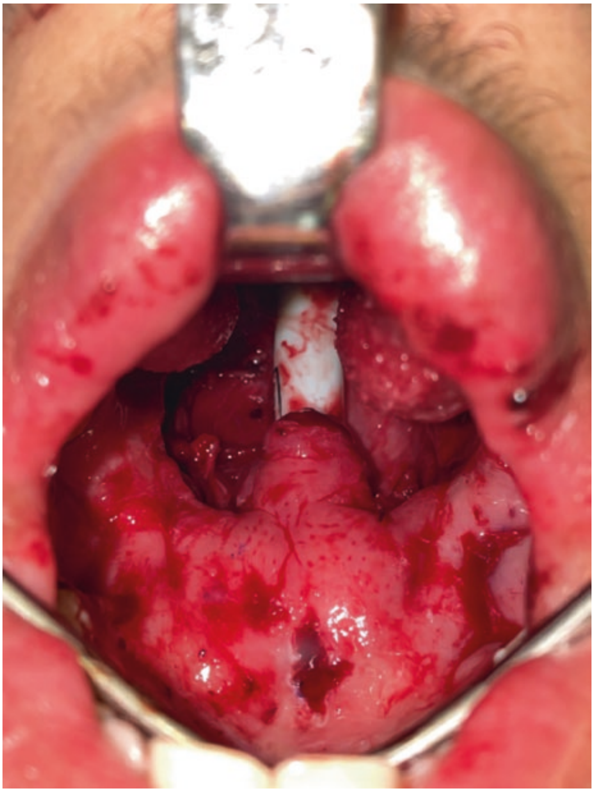

Fig. 40.6 Immediate postoperative period of the patient in Fig. 40.5

40.3 Complications

We had just one case of thread exposure after five days of postoperative with recovery without intervention and no velopharyngeal insufficiency or wound dehiscence. In this case, Stratafix® was used (Fig. 40.7). In our experience, it corresponded to 6% of the cases, differently from Gulotta et al. who reported extrusion more often when using V-loc® [10]. It took about 2 months for absorption to occur.

In one case in which the needle was inserted in the wrong way and the thread became very superficial, we used Nelaton® probe to cover the thread inside the mucosa of the palate and were able to remove the thread without any problems.

The healing process was good and the patient had no major pain in the postoperative period. The functional result of the surgical technique was not compromised.

Fig. 40.7 15° postoperative day with exposure of the Stratafix®

40.4 Conclusion

In our experience, barbed suture is an extremely promising technology in the field of pharyngoplasty. Partial results are excellent but we believe that further randomized trials are needed to demonstrate effectiveness. The use of barbed suture in the lateral-expansion pharyngoplasty reinforces stability, distributes tension, avoids damage of velopharyngeal tissues, and prevents collapse, with an important effect on long-term outcomes.

Acknowledgments Special thanks to the designer Sueli Loureiro Knoll for the exclusive drawings made for this chapter.

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Barbed Pharyngoplasties Experience in USA

41

Terrence Pleasant, Anuj Patel, and Paul Hoff

41.1 Introduction

Uvulopalatopharyngoplasty (UPPP) remains the most common palate procedure for OSA. Developed in the 1980s by Fujita in the United States, generations of otolaryngologists have been introduced to sleep surgery through the UPPP technique or direct modifications including those described by Fairbanks [1, 2]. Sleep surgery in the USA continues to be dominated by UPPP and remains a common procedure among otolaryngologists despite marginal outcomes [3]. In 1990, Friedman published his seminal paper describing predictors of success for tonsillectomy and UPPP using the Friedman Staging system [4]. UPPP has been associated with VPI, pharyngeal stenosis and voice change as well as troublesome foreign body and globus sensation. Despite these shortcomings, UPPP remains the predominant surgical treatment for OSA in North America amongst general otolaryngologists.

Advancements in palate surgery occurred primarily in South America [Cahali, lateral pharyngoplasty (LP)], Australia (Robinson, modified UPPP), Taiwan [Li, Relocation pharyngoplasty (RP)], and Singapore [Pang, expansion sphincteroplasty (ESP)] [5–8]. In the USA Woodson described trans-palatal advancement (TPA) and Friedman the palatal Z plasty (PZP) [9, 10]. All of the described procedures address retropalatal collapse; in addition, ESP and RP address lateral oropharyngeal wall collapse associated with hypertrophy of the palatopharyngeus muscle.

Palatal surgery in the American population began in the 1980s after Fujita et al. identified 3 types of anatomic upper airway obstructions: type 1: narrow oropharynx, type 2: low arched palate with large tongue, and type 3: hypopharyngeal

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_41

obstruction. Fujita et al. introduced the UPPP to address type 1 level of obstruction. This surgical procedure was designed to address a narrow oropharynx secondary to an enlarged uvula, pillar webbing, and enlarged tonsils with a normal palatal position. The steps of the UPPP include: (1) tonsillectomy or excision of the mucosa overlying the tonsillar fossa if tonsils are surgically absent; (2) a curvilinear incision from the inferior tonsillar fossa extending to the root of the uvula is made several millimeters lateral to the palatoglossal arch; (3) removal of the mucosae overlying the soft palate, tonsillar fossae, and lateral aspect of the uvula with preservation of the mucosal layer; (4) re-approximation of the mucosal edges with absorbable suture and then removal of the uvula. Fujita and colleagues performed the procedure in 12 patients diagnosed with obstructive sleep apnea and nearly 67% showed an improvement on polysomnogram and 9 patients reported significant improvements in symptoms.

BRP was first described by Mantovani in 2015 as the "Roman shades" technique [11]. By utilizing a continuous barbed suture, the load is distributed evenly across the entire wound. Tissue is preserved, repositioned, and anchored to dense fascia that includes both the pterygo-mandibular raphe and the midline aponeurosis of the hard palate posterior to the nasal spine. The primary advantages of BRP include tissue preservation, durable anchor points, reversibility (within the first few weeks), and the ability to customize the procedure (lateral wall, soft palate, both).

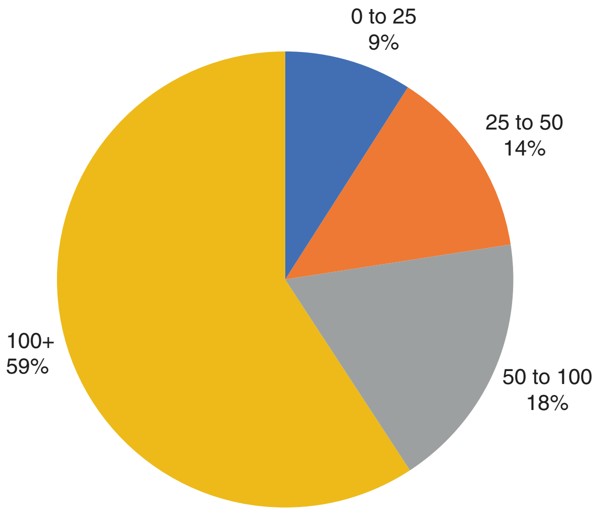
41.2 Survey Results

An informal survey of North American-based sleep surgeons was conducted in order to gain further insight into the use of BRP in this region. Responses were received from experienced sleep surgeons from all regions of the United States as well as Canada. Results of this survey showed a large number of sleep surgeries being performed yet very few of these were BRP. Fifty five percent of responding North American sleep surgeons had over 15 years of experience in sleep surgery, and 59% of respondents performed over 100 sleep surgeries per year (Fig. 41.1). However, 86% of these surgeons have never performed BRP, and of those that did perform BRP, this procedure represented a small fraction of the yearly sleep surgeries they performed. Taken together, the results of this survey suggest minimal use of BRP among North American sleep surgeons.

41.3 Barriers to Adoption

Barbed reposition pharyngoplasty has yet to take hold in North America as a standard practice procedure to address retropalatal and lateral wall collapse. According to survey data of North American based sleep surgeons, the main barriers to adoption for BRP are lack of awareness (29%), lack of evidence base (24%), favoring other techniques (24%), and poor outcomes (14%) (Fig. 41.2). There is likely some combination of these factors that lead to poor rates of

Fig. 41.1 Number of yearly sleep surgeries performed



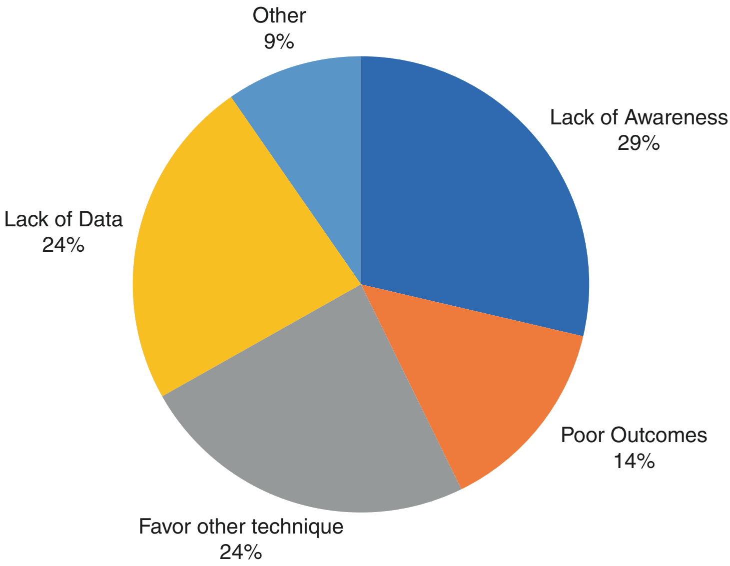


Fig. 41.2 Barriers to BRP adoption

adoption of BRP in North America. Of these polled surgeons, UPPP and ESP seem to be favored techniques for lateral wall collapse in North America. While many noted lack of awareness of BRP as an alternative technique, a number also felt that the evidence base for BRP was not substantial enough to supplant UPPP and ESP. This may be due to lack of familiarity with BRP literature as there have been no North American studies of BRP. The vast majority of BRP studies have come from Europe.

Since the introduction of UPPP in the 1980s to address retropalatal collapse, a number of modifications including BRP have been introduced in the field of sleep surgery. Our survey of North American sleep surgeons showed that lack of awareness and preferred alternative techniques are the main barriers to adoption of BRP for obstructive sleep apnea. Although BRP has shown promise in addressing OSA internationally, there has been some hesitancy in the adoption of this technique in the North America. With further exposure to and education about this technique in North America, BRP could become more widely adopted as a reliable method to address lateral wall collapse in OSA.

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Fellowship and Training in Barbed Pharyngoplasty

42

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42.1 Introduction

Obstructive sleep apnea (OSA) is chronic sleep related breathing disorders. Obstructive sleep apnea syndrome (OSAS) is defined as a combination of some comorbidities and/or symptoms plus repeated episodes of upper airway narrowing and obstruction during sleep. We can divide the symptoms to night and daytime symptoms. Common night symptoms are load snoring, apnea, nocturia and the day-times symptoms are excessive daytime sleepiness, fatigue, non-refreshing sleep, morning headache, irritability, and memory loss. Untreated OSAS can lead to many serious complications including cardiovascular disease and associated with lost productivity and motor vehicle accidents resulting in injury and fatality [1]. Unfortunately, OSAS is common syndrome. In one of the systemic review study for OSA prevalence showed At ≥5 events/h apnea-hypopnea index (AHI), the overall population prevalence ranged from 9% to 38% and At ≥15 events/h AHI, the prevalence in the general adult population ranged from 6% to 17%. The prevalence of OSA is more in men and the prevalence increase with aging and BMI [2]. Therefore, OSA patient should be evaluated properly and the gold standard test to diagnose OSA is polysomnography (PSG) [1]. Currently, the first-line treatment for OSA patient is CPAP but unfortunately adherence rates to the treatment remain unacceptably low [1, 3]. Therefore a valid alternative treatment is required and the main alternative treatment is surgical treatment [1]. There are many types of surgeries for OSA patients available which are showed significant improvement in OSA patients. Barbed pharyngoplasty is considered as one of important surgeries to treat soft palate and pharyngeal collapse in OSA patients [4]. Barbed pharyngoplasty approved to be easy to learn, safe and effective procedure [4, 5].

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_42

Barbed sutures are offered in both bidirectional and unidirectional formations. Bidirectional sutures have barbs in both directions, so that one end anchors the other. This enables tissue approximation without the need for a securing knot. Unidirectional barbed sutures have barbs in a single direction, secured by a looped end [6]. In OSA surgeries knotless, bidirectional and reabsorbable barbed sutures are used which is more stable than single knot in normal sutures as the pulling force is divided along the entire thread [4, 6].

Barbed sutures is currently used in many types of pharyngoplasty surgeries like barbed anterior pharyngoplasty, barbed expansion sphincter pharyngoplasty, barbed relocation pharyngoplasty, barbed lateral pharyngoplasty, etc. Choosing the types of surgery depends on the patient evaluation and surgeon expertise but all of these surgeries are approved to be efficient in many studies [4, 5, 7].

As the OSAS is a common disease with many health and social problems, many patients not tolerate he first-line treatment which is CPAP. Other types of treatments should be considered including surgical treatment. So the need for OSA surgeries fellowship is very important as other surgical subspecialties.

42.2 OSA Fellowships

OSA surgery fellowship program is the identified component of Otolaryngology where the fellow will devote major part of his time towards OSA subspecialty.

OSA fellowship, as other subspecialties fellowships, has objectives and aims. The aims of OSA fellowships are to educate and train the fellows so that they become competent OSA surgeon with high skills and knowledge.

Of course learning barbed pharyngoplasty is one of the main objectives in OSA surgeries.

42.3 Our Experience

I did my fellowship in Morgagni-Pierantoni Hospital in Forli, Italy with Professor Vicini and the team for one year. In our experience, one year fellowships in busy center is enough to learn patients evaluation and different types of OSA surgeries, including barbed pharyngoplasty.

42.4 Pre Fellowships Requirement

A pre fellowship is very important. Hence OSA fellowship is subspecialty fellowship, the fellow is expected to know the anatomy of nose, oral cavity, pharynx, and neck in detail and have idea about pathophysiology, evaluations of patients, and the treatment options for OSA patients. Watching videos of different surgical technique, including barbed pharyngoplasty, is important for faster learning and shortening the time of learning.

42.5 What We Learn During the Fellowships

Two main things that we learn during our fellowship

- Proper patients evaluation.
- Gaining surgical skills.

42.6 Proper Patient's Evaluation

During one year fellowship, we rotate between outpatient's clinic, admitting patients wards, and operation theater.

In the clinic, we see two types of patients, either pre-surgery patients or post-surgery patients. In pre-surgery patients we do comprehensive evaluation for the patients to diagnose patients, to know the severity of OSA, and to know the best treatments options. To achieve this aims there is ready-made template which includes history and clinical examination finding (Table 42.1). In addition to clinic template, Drug Induced Sedation Endoscope (DISE) is an important tool to complete the evaluations of the patients and become more popular to evaluate the site and types of obstruction for better treatment plan and is usually considered before barbed pharyngoplasty. Learning proper DISE is considered as one of main objectives for OSA fellowships. There are different protocols for DISE depending on the institutions but we learn during our fellowship Forli's DISE protocol [8].

Post surgery we evaluate the improvement of the patients symptoms and signs. We examine the surgical site looking for any complication like extrusion of the thread, pharyngeal insufficiency, scaring, etc.

42.7 Surgical Skills

As we mention before in pre fellowships, the fellow is expected to know the basic anatomy and pathophysiology. Fellow also expected to know how to perform tonsillectomy and be familiar with tonsillectomy set instruments. Hence in barbed pharyngoplasty we used almost same tonsillectomy set instruments, learning barbed pharyngoplasty is much easy. In our opinion fellow need to observe at least 3 surgeries in different types of barbed pharyngoplasty and should perform at least 3 to 5 surgeries under supervision to know how to handle needle holder in different directions before working independently. But it's better to have one year fellowship in busy center to have chance to observe and perform some difficult cases like revision cases and to observe the expected complications and to know how to deal with the complications.

Table 42.1 OSAS consultation template for outpatient's clinic in Morgagni-Pierantoni Hospital in Forli, Italy

OSAS consultation	
To the kind attention of…………………………..	
Today I've seen Mr/Mrs/Ms……………………… M/F	
Age………………………………………………..	
Phone number…………………………………..	
Mail address…………………………………….	
He/She comes to my observation for sleeping disorders	
The patient comes to my attention for • on his/her own initiative • partner request • consultation required by GP • consultation required by other ENT/stomatologist • consultation required by sleeping doctor/pulmonologist/neurologist	
He/She comes for • in-depth analysis • therapeutic planning • surgery • second opinion	
Clinical examination has been done according to EOS DRS 2020 criteria, accredited by Italian ENT Society and Italian Sleeping Medical Society	
The patient complains about • usual snoring since … yrs • nocturnal obstructive apneas since … yrs • occasional awakenings with feeling of suffocation every … weeks • … nocturnal awakenings for micturating • restless sleep with nightmares • frequent legs movements during night • significant nocturnal sweating and dry mouth • variable frequency insomnia • acid throat or mouth regurgitation	
His/her partner refers nocturnal noise like "donkey bray" • Yes • No • Restless sleep and consequent daily sleepiness. • Somnolence takes to sleep and patient is not able to stay awake. • Problems in concentrating and memorizing. • Loss of energy in his/her job and other activities. • Sudden falls, legs collapse sometimes related to emotional condition. • Waking up headaches. • Sexual disorders • Nasal respiration is inefficient (VAS and NOSE score).	
Familiar history: • Snoring/Apneas • Sudden nocturnal death	
Comorbidities:	
• High pressure	Therapy
• Diabetes	Therapy

Table 42.1 (continued)

• Hypercholesterolemia		Therapy					
• Arrythmias		Therapy					
• Chronic Bronchitis/Asma		Therapy					
• Anxiety		Therapy					
• Major Depression		Therapy					
• Previous heart attack		Therapy					
• Previous stroke		Therapy					
• Hypothyroidism		Therapy					
• Down syndrome							
• Syndromic facial dysmorphism							
• Respiratory allergies							
• Previous malignant tumors							
• Previous car accident							
• Bladder and urinary disorders							
• Low pressure especially when he/she suddenly stands up							
Neurological disorders							
Previous surgery: • Functional nasal surgery • Adenotonsillectomy • Cleft lip and palate surgery • Snoring palatal surgery • Other OSAS surgery • Orthognathic surgery • Bariatric surgery • Cervical spine surgery • Other (…)							
Weight	Height	BMI					
Loss or gain of weight in the last 10 years (±)							
Previous sleep analysis:							
Type	Date	Reliability	AHI	RDI	ODI	%sat<90%	Positioning
Panorex: • No significant alteration • Ipodentulia and/or paradontosis • Functional and structural TMJ alteration							
Telencephalic X-ray in profile: • Retrovelar PAS <10 mm • Retrolingual PAS <10 mm • Vertical tongue • Hyoid-Jaw distance … mm • Base tongue hypertrophy • Adenoids							

(continued)

Table 42.1 (continued)

Facial CT: • Septal deviation • Inferior turbinate hypertrophy • Concha bullosa • Nasal polyposis		
Neck MRI: • Base tongue hypertrophy • Palatine tonsils hypertrophy • Adenoids		
Epworth Scale: ESS score …		
Physical examination: • Phenotype and Habitus: o Acromegaly o Hypothyroidism o Marfan o Syndromic o Down o Other (…)		
• Neck circumference: (…) cm		
• External nose deviation		Grade 1,2,3,4
• External valve collapse		
• Internal valve collapse		Grade 1,2,3
• Caudal septal deviation		
• Septal deviation		Grade 1,2,3,4
• Inferior turbinate hypertrophy		Grade 1,3,3,4
• Concha buollosa and/or spongious/cancellous		
• Adenoids		Grade 1,2,3,4
• Short tongue and lip frenulum		
• Interincisive distance at the maximum mouth opening: … mm		
• Friedman Palate Score		Grade 1,2,3,4
• Mallampati Score		Grade 1,2,3,4
• Tonsils Score		Grade 1,2,3,4
• Palate Phenotype (Tucker Woodson)		
• Moore Lingual Score		Type A,B,C
• Modified Cormack-Lehane		Grade 1,2,3,4
• Muller Maneuver	Retropalatal	Grade 1,2,3,4
	Retrolingual	Grade 1,2,3,4
• Jaw protrusion Test		Grade 1,2,3
• Panting Test		Pos/Neg
• Retro/Micrognathia		Grade C,D
• Superior Maxilla narrowing		

Table 42.1 (continued)

N			
O	AP	LL	C
H	AP	LL	C
L	SG	G	
Previous therapy: • Wait and See • Weight loss • CPAP • MAD • Surgery • Positioning therapy			
Refused, briefly used, suspended, ongoing with satisfaction			
Diagnosis: • Snoring • Upper Airways Resistance Syndrome • OSAS			
Mild	Moderate	Severe	
Positional			
REM-Related			
APOC: I IIa IIb C			
• Overlap Syndrome • Stridor			
Recommendations: • In-depth analysis to complete this clinical examination • Polysomnography and re-evaluation • DISE • Neurological visit • Pneumological visit • Oral surgery visit (MAD) • Positional therapy • Surgery • Consultation in II level ENT Centre • Consultation in Maxillo-Facial surgery Centre • Consultation for Bariatric surgery			
Conclusion:			

42.8 Applied New Technique After Fellowships and its Difficulties

We learn during the OSA fellowship three main things, proper patient evaluation in clinic, proper DISE, and surgical skills.

Regarding patients evaluation in clinic was not difficult to applied in our country as all instruments and tool for proper evaluation are available in most of ENT clinic. Currently, we use same Forli Hospital template for OSA evaluation with some minor modification.

For DISE, also we tried to apply Forli' protocol and after discussion with our anesthetics, there were two main problems. First problem we don't have minor theater so we need to do DISE in the main theater bed and the bed is too small to turn obese patient during DISE but we solve the problem with bed extension. The second problem, we don't have PSG inside theater so currently we do DISE without PSG but we monitor the saturation and we observe the chest and abdominal movement as well as endoscopic finding.

Regarding new barbed pharyngoplasty technique, usually it's not easy to apply new technique in any country or hospital. Barbed pharyngoplasty was not difficult to apply in our Hospital as there are many studies in literatures which approved the safety and efficiency of barbed pharyngoplasty surgeries. In Oman also, it was not difficult in convenes patient to do barbed pharyngoplasty as usually in general patients like new approved procedure. For the instruments, as we mention, we use tonsillectomy set in barbed pharyngoplasty which is available in all ENT hospitals. There was only one problem we faced. In our hospital we don't use barbed sutures for any types of surgeries therefore their introduction is in progress.

42.9 Conclusion

OSAS is common syndrome with many health and social problems. So fellowship in OSA for proper training is required. Good patient's evaluation is essential to choose the best treatment options for the patients. Barbed pharyngoplasty is safe, efficient, and easy to learn procedure and considered as one of main surgical options to treat OSAS as single level or as part of multilevel surgeries.

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Future Perspectives

43

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Any new surgical option is devised to achieve many different goals:

- To completely address the underlying problem.
- To be safe without any or significant complications.
- To be easy to perform, teach, and learn.
- To be quick.
- To be cheap.
- To be effective for a long time.

Does BRP fulfill all these requirements? Absolutely not. This answer gives us the opportunity to search for future lines of development of the technique.

There are many directions for improvement.

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C. Vicini et al. (eds.), *Barbed Pharyngoplasty and Sleep Disordered Breathing*,
https://doi.org/10.1007/978-3-030-96169-5_43

43.1 Point #1: Patient Selection

Is it possible to get a better patient selection with a higher success rate? Probably yes. A more precise, correct, and pragmatic functional phenotypization may allow to rule out situations less suitable for surgery, such as conditions that are just functional rather than anatomical. Being able to select cases in which the anatomical contribution to OSA is greatly superior to arousal thresholds and high loop gains would be a great support for the surgeon. It is true for barbed pharyngoplasty as for all the anatomical approaches to OSA: a sleep surgery, MADs, or bariatric.

For any custom technique it is crucial to define in detail the required modifications to apply. A more extended use of DISE and the possibility to rely upon an available and sustainable dynamic MRI will give us increased possibility to plan the best possible surgery.

Summarizing: a better customized procedure is probably more effective.

43.2 Point#2: Barbed Suture Technology

The use of a barbed suture is the mainstay of BRP. The perfect barbed technology for pharyngoplasty does not exist so far. What we are using now is a commercially available material devised for many applications, different from pharyngoplasty. The ideal thread should be very stable in the tissues with a high grip on the surrounding muscles. This feature is produced by a combined action of the number, dimension, and shape/angle of the barbs with their 3D array in the space (single plane, spiral, etc.). Soft palate is an extraordinarily mobile structure, mainly composed by very delicate muscles with a complex dynamic. We expect to have in the future new products with increased tissue anchoring capability. What is expected is a reduced relapse along the time. This should produce a more effective long-term collapse prevention.

Furthermore, the future materials should be softer, more pliable, and less rigid. The challenge is to provide a smoother post op phase for the patients and a reduced extrusion rate.

In addition, bidirectional barbed sutures are not always available in the suitable combination of size and length of the thread, including the required not cutting needle.

The possibility to explore different kinds of suture materials deserves a special mention, especially to elastic sutures. Conceptually, a suture with some degree of elastic recoil appears as a great step forward from a mechanical point of view. So far permanent elastic sutures are under evaluation and to some extent available for different applications. The idea of inserting into the palate a permanent elastic framework to prevent collapse could be a true theoretical revolution in the palate-barbed-suture world. No more rigid frameworks to dampen vibrations as in Mantovani blind Roman, nor an anchoring suture as in Vicini BRP, but an active structure suspending a dropping palate and a collapsing pharynx dynamically. In the classical barbed pharyngoplasties, reabsorbable sutures are replaced with time by a scar tissue. The permanent scar is what determines the long-term effects of the procedure. In case of elastic suture its action is expected to last for an indefinite time. The real problem of this solution could be the tissue reaction to a permanent foreign body, which is an open direction for future research.

43.3 Point#3: Technique

After the first historical published palate barbed techniques, many eponimic variations were described according to the different experiences and goals. Naturally, many new techniques will be devised, studied, published, and discussed. Therefore, it is quite clear that in the future many details may be modified. First of all, the level of muscle and mucosa manipulation. Different shapes of palatopharyngeal flaps may rise in different ways, different degrees of muscle release may be preferred, additional mucosal flaps may be integrated. It is an open question how many suture loops are needed for best results. Further work is needed to address this question.

43.4 Point#4: Suture Deployment

Is it possible to deploy barbed sutures inside the palate just in a very conventional way as with traditional needle and needle holder? Or are other technologies possible? A partial answer seems to come from the preliminary studies by an Italian Group from Genova. Dr. Mauro Pagano developed an original idea for an alternative suture deployment. Different sizes of Polidossanon (PDO) barbed sutures may be introduced into the tissues by means of a system of dedicated needle holder and hollow needles nemed as ("MAG 1"). The system allows a precise suture introduction into different planes with different angulations. The procedure is devised as completely submucosal (Fig. 43.1).

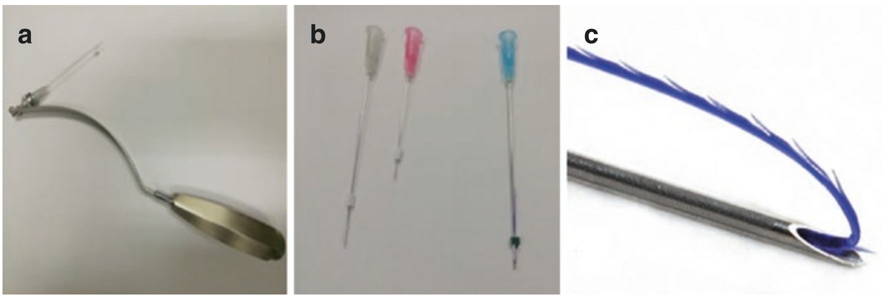

Fig. 43.1 The MAG 1—New system to the barbed suture introduction into submucosal tissues; (**a**) suture introduction system; (**b**) different needles used to introduce the barbed suture into the tissues; (**c**) passage of the suture through the introduction needle

43.5 Point#5: Planned Revision BRP

To some extent, BRP may be considered as a sort of "Palate Lifting," with the same philosophy of rhytidectomy. If you are considering a facelift, it is important to have realistic expectations. A facelift usually lasts 5 to 12 years, after which it might need to be repeated. It can make you look temporarily younger, but it cannot stop the aging process. Revision is possible. Recurrence is a well-known event in ENT surgery. Unilateral or bilateral recurrent nasal polyposis prevalence following ESS was 35% at six months, 46% at 12 months, and 41% at 18 months. Revision is very common. However, patients with granuloma submitted to only surgery have high recurrence rates, ranging from 50% to 92%. Laser secondary session possible. Grommets may remain in the drum for up to 12 months before being extruded. After grommet extrusion some children require reinsertion due to recurrent otitis. The original Stanford protocol relied on a stageted (Phase 1&2) approach to avoid unnecessary surgery. It did not address the issue of surgical relapse, a common concern among sleep medicine specialists. BRP is a noninvasive palatoplasty possibly included into a multilevel procedure with nose surgery. It proved to be effective in a short time follow-up. In case of snoring or apnea recurrence, a second DISE-guided procedure may be offered as backup solution, according to the proved acceptance by the patients, as well as a multimodal integration (positional or MAD). Specific informed consent should be considered.

43.6 Point#6: Improved Visualization

Finally, any new technology devised for improving surgical field visualization may be considered a step forward in surgery. In barbed pharyngoplasty, some of us are studying the use of a 3D scope to increase surgical precision. Storz Exoscope VITOM 3D is now a new way to obtain a tridimensional HD view of the oropharynx in a wide screen in front of the surgeon. The image is easily available also for the assistant surgeon and for all the attendees in the OR (for teaching purposes). Tonsillectomy and pharyngoplasty are easily carried out just while looking at the screen where the anatomy is magnified, well-detailed, and reproduced in a 3D way. By means of special blades with a central window, a midline glossectomy is possible without addictional maneuvers of exposure. Finally, replacing the exoscope with a 30-degree andoscope, a wide view of the tongue base allows for a tongue base reduction if required. This cohomprensive and modular setting seems highly promising for multilevel procedures in terms of precision and velocity.