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Expansion sphincter pharyngoplasty and palatal advancement pharyngoplasty: airway evaluation and surgical techniques

B. Tucker Woodson, MD,[a] Matthew Sitton, MD,[a] Ofer Jacobowitz, MD, PhD[b]

From the [a]Division of Sleep Medicine, Department of Otolaryngology and Communication Sciences, Medical College of Wisconsin, Milwaukee, Wisconsin;
[b]Columbia University and Hudson Valley, Ear, Nose & Throat PC, Middletown, New York.

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Multiple palatopharyngoplasty techniques are available for reconstruction of the upper pharyngeal airway. To select appropriate procedures, the surgeon requires classification methods, but traditional staging systems only describe levels of obstruction and do not relate sufficient anatomical detail to specify an intervention. A method of awake, upper airway evaluation is described, which allows the surgeon to direct specific surgical procedures to particular luminal shapes and anatomical structures. Expansion sphincter pharyngoplasty is a procedure for treatment of lateral pharyngeal stenosis, where rotation of the palatopharyngeus muscle is performed to widen the pharynx and advance the soft palate anteriorly. Palatal advancement pharyngoplasty is a technique for treatment of posterior retro-palatal obstruction which results in anterior palatal advancement. Surgical techniques and management are described.

Uvulopalatopharyngoplasty (UPPP) was first described by Fujita for the treatment of obstructive sleep apnea syndrome (OSA).[1] UPPP evolved from earlier palatopharyngoplasty techniques and has continued to evolve with multiple UPPP techniques now described. UPPP's defining elements include surgery directed at reconstructing the upper pharyngeal airway by removing or modifying tissues of the palate, uvula, and pharynx with primary wound closure. This contrasts with other procedures, which simply ablate or remove tissue and then allow for secondary healing and scar formation. As techniques evolve, controversy arises over applying and comparing outcomes. Some newer techniques have been inexplicably excluded from systematic reviews despite high-level evidence supporting their use. The goal of this description is to better describe techniques and diagnostic evaluation for two current palatopharyngoplasty techniques for OSA.

A basic tenet of upper airway surgery is that the anatomy and structure of the upper airway are variable.[2,3] Therefore, surgery for OSA must address this variability and be able to correct different structural abnormalities. Additionally, reconstructive surgeries must improve form and function without negatively altering other functions of the upper airway, including smell, taste, swallowing, and speech.

Airway evaluation

It is proposed that the upper pharyngeal airway has definable phenotypes.[4] The upper pharyngeal airway is not a simple conduit but a complex structural lumen. Individual characteristics, critical for function, include size, length, shape, and wall (interface) smoothness and wall compliance. Multiple craniofacial and soft tissue abnormalities contribute to the final structure. Historically, assessment of upper airway structure has focused on soft tissue and skeletal abnormalities, such as increased palatal thickness, palatal length, tongue size, tongue palate contact, and lateral wall thickness. Although these features may be predictive of OSA risk, they have yet to significantly improve application of surgery to the upper airway.

An alternative approach is to describe the structure of the pharyngeal isthmus and lumen and not to limit description to the soft tissues surrounding the pharynx. The lumen is the primary pathology of OSA structure. This pathology is defined

Address reprint requests and correspondence: B. Tucker Woodson, MD, Department of Otolaryngology and Communication Sciences, Medical College of 9200 West Wisconsin Avenue, Milwaukee WI, 53226.
E-mail address: bwoodson@mcw.edu.

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Figure 1 Sagittal view of the pharyngeal isthmus. The palate is composed of osseous, aponeurotic, and muscular segments. The lateral wall structures include the levator veli palatini (anterior eustachian tube fold), salpingopharyngeus, and palatopharyngeus.

and described by variable soft tissue and skeletal anatomy in adults. Characteristics of the lumen include, but are not limited to, the cross-sectional size and shape of the pharyngeal isthmus, which are more elliptical and flattened in OSA patients. An elliptical airway shape is a biomechanically weaker structure that is more easily collapsed at less negative pressures than a similar-sized circular airway.[5] Part of the goal of surgery is to create a more favorable shape. Procedures that address the lateral wall of the pharyngeal isthmus and create a more favorable ovoid shape may have an advantage over those that do not address the lateral wall.[6]

Previous methods of airway classification have included the Friedman and the Fujita classification methods. The Fujita method attempts to describe levels of obstruction. The method provides little specific descriptive information beyond oropharyngeal (type 1), hypopharyngeal (type 3), or combined (type 2) levels of obstruction. This lack of description has potentially perpetuated the concept that most palatopharyngoplasty techniques are equivalent. As an alternative, the Friedman method has a higher positive predictive value especially for Friedman stage I and UPPP outcomes. However, UPPP success for Friedman stages II, III, and IV is often low. A major deficiency of both methods is that they do not describe the airway structure and, therefore, cannot readily direct the surgeon as to which specific techniques best reconstruct the retropalatal airway. For this another method is required.

The retropalatal airway is the pharyngeal isthmus (Figure 1). To simplify a complex lumen, the lumen of the isthmus may be conceived as having anterior, posterior, and lateral walls; a roof; and floor. Anatomic structures define these walls and define the isthmus and lumen. For example, major defining structures include (1) anteriorly: soft palate, hard palate, and choanae (septum, posterior turbinates); (2) laterally: auditory tube, salpingopharyngeus muscle, palatopharyngeus muscles, and the superior pole of the palatine tonsils; (3) posteriorly: posterior wall and adenoids; (4) inferiorly: the isthmus is bound by the inferior margin of the soft palate and velopharynx.

It is widely accepted that the pharyngeal airway is smaller in OSA patients and snorers than in normal patients. The other structural characteristics that vary between patients are less well defined.[7] For example, a recent review of airway structure identified that in approximately one-half of patients, the narrowest level was at the distal retropalatal segment (defined as 20 mm or more inferior to the hard palate), whereas in the other half, the narrowest segment also included the more proximal retropalatal segment (10 mm inferior to the hard palate).[8] The differences were not explained by baseline differences in palatal length among OSA patients but were associated with differences in retropalatal airway shape.

Previous authors have described two general patterns of velopharyngeal shape and closure (Figure 2).[9] Patterns include a "flat" or coronal pattern and a "deep" or circular pattern of closure. Anatomically, in the flat pattern, the soft palate is close to the posterior pharyngeal wall in contrast to a deep pattern of closure where the upper soft palate is further distanced from the posterior pharyngeal wall.

Differences in structure are associated with different cross-sectional airway shapes and vertical palatal shapes (Figure 3). Such a finding should not be unexpected. In the flat pattern, the airway is oriented coronally, and there is relatively little lateral wall musculature. The palatopharyngeus muscle is vertically oriented, parallel to the posterior pharyngeal wall, and more perpendicular to the hard palate. In contrast, with the deep or circular pattern, the muscle courses more obliquely in the pharynx. Both the soft palate and palatopharyngeus muscles are more parallel to the hard palate and more acutely angulated to the posterior pharyngeal wall The palatopharyngeus muscle is often more hypertrophic or associated with palatine tonsil enlargement. Additionally, an intermediate type has been described with an oblique upper segment (above the palatal genu or "knee point") and vertical segment below the genu. Although these general types provide a basis for description, additional structures and factors including adenoid enlargement, increased size of the lateral wall, tonsil hypertrophy, and post-tonsillectomy scar may affect the lumen.

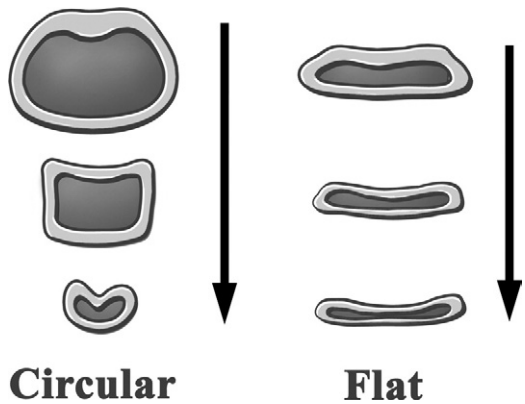

Figure 2 Pharyngeal narrowing and pharyngeal closure differ among individuals with different cross-sectional pharyngeal shapes.

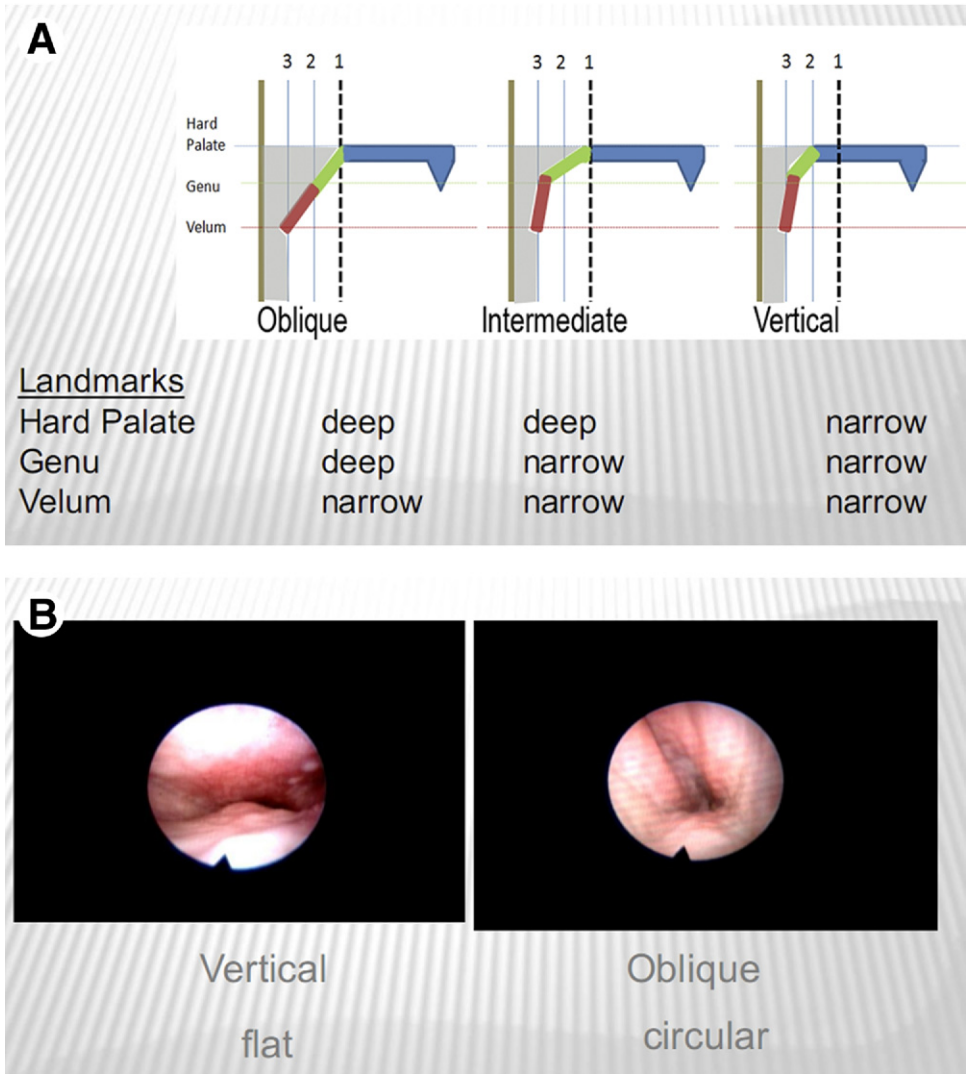

Figure 3 (A) Vertical palatal sagittal view: configurations of vertical, intermediate, and obliquely oriented palates are schematically presented with corresponding anteroposterior distance at landmarks. (B) Corresponding endoscopic view and vertical and oblique palatal shapes. Note proximal anterior–posterior narrowing at arrow head with flat shape and relative anterior–posterior patency with oblique shape. (Color version of figure is available online.)

Although it is recognized that upper airway anatomy is a continuum, a pattern of airway phenotypes may be described. In the vertical type, the pharyngeal isthmus is narrow near the level of the hard palate, and the airway shape is flat. In the oblique pattern, the pharyngeal isthmus is larger at the hard palate and narrow at the velopharynx, which is often deeper and more ovoid in cross-sectional shape.

A better understanding of the upper pharyngeal anatomy provides a rationale why UPPP failure using traditional techniques often occurs at the velopharynx or retropalatal area. Aggressive resection of the soft palate may result in complications without correcting the underlying structural abnormalities. Over resection also increases risk of pharyngeal stenosis, pharyngeal insufficiency, and worsening mouth leak with attempts to use nasal continuous positive airway pressure. Instead of resection, methods incorporating reconstruction are described.

The expansion sphincter pharyngoplasty

Expansion sphincter pharyngoplasty is a reconstructive technique and variant of UPPP, used in isolation or in combination with other surgical maneuvers.[10] The procedure is conceptually based on repositioning the underlying muscular structures of the pharyngeal isthmus and palate to enlarge the lateral pharyngeal airway as well on advancing and superiorly positioning the margin of the soft palate. Expansion sphincter pharyngoplasty is the opposite of the sphincter pharyngoplasty that is used for velopharyngeal incompetence, where the palatopharyngeus muscle is elevated off the pharynx and the pedicle is rotated medially to narrow the velopharyngeal sphincter. By contrast, in expansion sphincterplasty, the palatopharyngeus muscle pedicle is rotated anteriorly, superiorly, and laterally to enlarge the velopharynx. The procedure is not based on tissue excision, although it can be combined with excisional techniques such as tonsillectomy, uvuloplasty, or other palatopharyngeus interventions as appropriate.

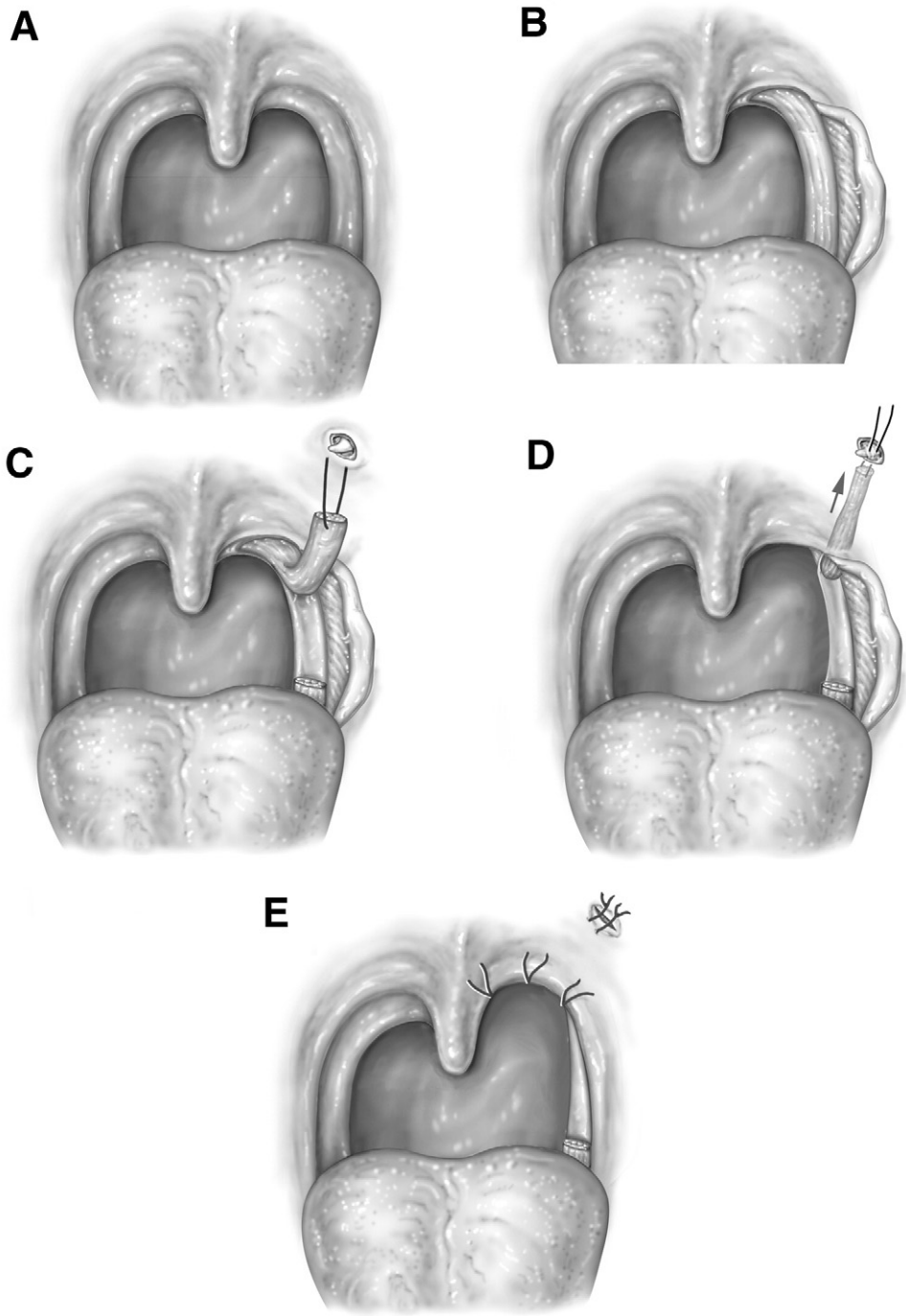

Figure 4 Expansion sphincter pharyngoplasty technique. (A) Preoperative view of the oropharynx; (B) exposure of the palatopharyngeus (vertical fibers); (C) elevation of the palatopharyngeus; (D) rotation and tunneling of the palatopharyngeus toward the hamulus; (E) suture suspension and approximation.

Surgical procedure

The technique is most commonly done under general anesthesia, with the patient in the supine position. In a small number of patients who have had previous tonsillectomy, a modified procedure can be performed under local anesthesia. The technique may be incorporated with other airway reconstructive procedures based on the patient's anatomy and disease. For descriptive purposes only, the procedure will be described in steps (Figure 4).

Step 1 (Figure 4A): The airway is examined. A laryngeal mirror is used to view the nasopharynx while gently retracting the uvula. Patients for the procedure should have an oblique pattern of palatal shape such that with this examination, the proximal pharyngeal isthmus is more open and the narrowing is close to the level of the velopharynx (approximately 1-1.5 cm). Narrowing closer to the hard palate usually may not be addressed by this as an isolated procedure. The size and position of the tonsils are noted as well as the size and location of the palatopharyngeus muscle, which is the primary structure of

the posterior tonsillar pillar. The presence of an abnormally positioned medialized carotid artery must be ruled out. The palate is palpated for a submucus cleft. India ink or similar marker is used to mark the position of the hamulus on the lateral and superior portion of the soft palate. Local anesthesia with epinephrine is injected, bilaterally, at the superior pole at the plane of the tonsil/constrictor muscle, on each side of the uvula, and inferior to the palpable tip of the hamulus.

Step 2 (Figure 4B): A bilateral tonsillectomy is performed. Care is taken to preserve maximum mucosa of the pillars. Preserving mucosa that avoids excess scar as well as lessening closure under tension is critical for ultimate success.

Step 3 (Figure 4C): The palatopharyngeus muscle is identified in the tonsil fossa. The goal is to dissect adequate muscle bulk and length to create a sling to rotate for the expansion technique. Often in OSA, the muscle is enlarged and only a portion of its circumference needs to be dissected. The length will vary on the direction of rotation but is generally one-half to two-thirds the length of the muscle in the fossa. In most cases, dissection is begun by dissecting the medial border of the muscle from the pillar mucosa. This may be done with fine scissors or a low-power cautery. A rim of muscle may be left, and it is very important to avoid damaging the pillar mucosa because this will result in lateral wall scarring postoperatively. The muscle can then be dissected laterally to create a "strip." It cannot be emphasized enough that the constrictor muscle layer is not violated during this elevation. In addition to alterations in swallowing, which are not observed with routine expansion sphincter pharyngoplasty, major vascular and neurologic structures lie lateral to this muscle. The glossopharyngeal nerve may on occasion run superficial, and care needs to be taken during elevation of the palatopharyngeus muscle. The constrictor muscle can be readily identified by the more horizontal direction of its muscle fibers. For most patients, bleeding from the palatopharyngeus is minor as compared with the potential for bleeding from the constrictor muscle, which is far more vascular. A small right-angle hemostat may also assist in dissecting the palatopharyngeus strip. Inferiorly, the muscle is transected with cautery and is then elevated superiorly to the level of the margin of the soft palate. The result is the creation of a muscle pedicle attached posteriorly and laterally to the lateral wall and pharyngeal constrictor muscles. The pedicle remains in continuity with the palatopharyngeus muscle in the distal soft palate. When the muscle is rotated superiorly and laterally, the airway is increased in both an anterior–posterior direction (by pulling on the soft palate) and increased in a lateral direction (but traction on the lateral wall muscles).

Step 4 (Figure 4D): Hamulus incision. An incision is made through the palatoglossus muscle at the superior pole of the tonsillar fossa. It is directed superiorly and laterally to the anchoring point. This anchoring point is often inferior to the palpable tip of the hamulus. On the palate, the incision is through mucosa and fibroadipose tissue and does not violate the palatal muscles (other than the palatoglossus). The palatopharyngeus muscle pedicle is then rotated, and the muscle is sutured with 2 mattress sutures (Vicryl 2-0 taper-round needle). The primary suture is a "tendon stitch" (or figure of 8 suture) through the "cut" end of the muscle bulk secured to the submucosa on the lateral aspect of the hamulus incision. This suture is an aggressive horizontal mattress suture that aims to grab as much submucosal connective tissue as possible. The second suture is a mattress suture whose first arm is placed through the muscle, into the connective tissue near the hamulus, and finally out the mucosa. The second arm repeats this trajectory. The mucosa of the hamulus incision is then closed. If tenting and tightness of the palate is present (most common), a dorsal palatal flap is performed.

Step 5 (Figure 5): Dorsal palatal flap. A mucosal incision is made on the ventral palate next to the uvula and connected to the hamulus incision in such a direction as to make it to its shortest length and minimize removal of ventral mucosa. This mucosa is then elevated to the free margin of the soft palate. The uvula is then grasped and pulled anteriorly to provide visualization of the dorsal palatal mucosa. A mucosal incision is made parallel to the uvula and carried superiorly. The soft tissue between the ventral and dorsal incisions is then incised resulting in a laterally and superiorly based mucosal flap. This flap can then be rotated to cover the lateral wall defect without tension. The net result is also to lengthen the uvula. The flap is closed with monofilament absorbable sutures. The anterior and posterior tonsillar pillars, which can be apposed without tension, are closed. The fossa is left open inferiorly if mucosal tension is present.

Step 6: Uvuloplasty. This portion of the procedure will vary on the size and redundancy of the uvula. The distal tip may be amputated, and lateral "fish mouth" excisions may be performed to narrow and debulk the uvula. Uvular preservation should be the goal in most cases because it performs important functions related to airflow, mucus flow, and swallowing. However, in cases of marked enlargement or severe tissue redundancy, more excision of tissue may be required.

Palatal advancement pharyngoplasty

Palatal advancement pharyngoplasty is directed at correcting the narrowing of the proximal isthmus in the nasopharynx. The pharyngeal isthmus airway space includes the nasopharyngeal airway behind the palate (retropalatal area) and has four segments. The segments include the nasopharynx proper that is behind the choana, the airway associated with the palatal aponeurosis, the muscular segment of the soft palate, and the velar segment of the soft palate. Most traditional UPPP techniques are focused on the velar segment of the soft palate and fail to address significant abnormalities of the muscular and aponeurotic segments. Palatal advancement addresses abnormalities of the aponeurotic and muscular segments. Upper airway evaluation of these segments is discussed earlier. It is critical to appreciate that there is wide variability in palatal anatomy in patients with sleep apnea. Furthermore, it is not the level of obstruction that is critical in surgical decision making but rather it is important to identify the anatomic structures that are contributing to specific narrowing of the airway. Reconstructive procedures can then be directed at these elements.

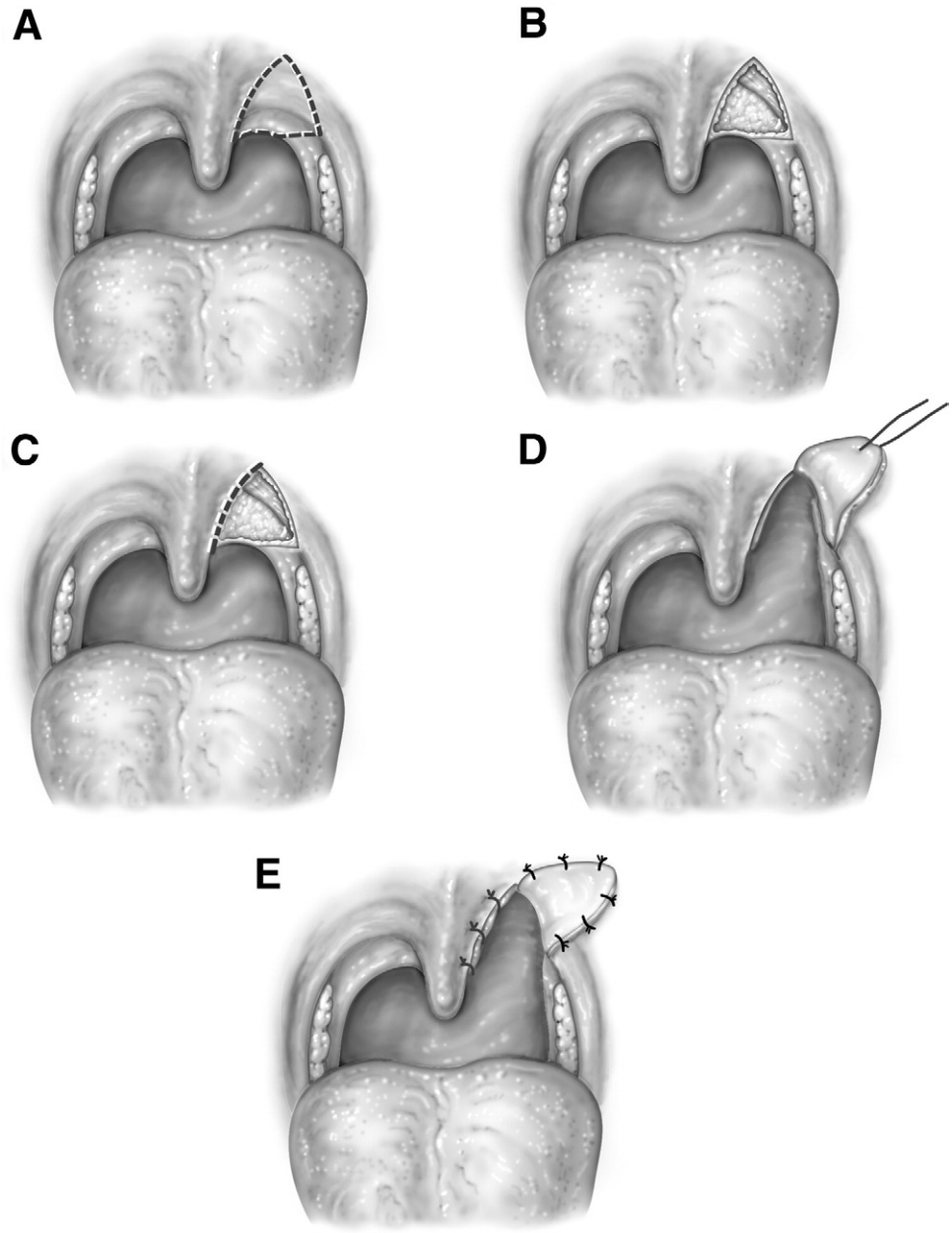

Figure 5 The dorsal flap is shown (A-E). For descriptive purposes, ventral palatal mucosa is removed (B). Dorsal palatal mucosa can then be incised along the length of the uvula (C), to create a laterally and superiorly based flap that can be rotated to cover lateral wall defects.

Palatal advancement is indicated for patients with retropalatal obstruction, particularly for those with superior obstruction localized to the aponeurotic and muscular palatal segments (Figure 1). In addition, palatal advancement is indicated for patients with persistent OSA after laser-assisted uvulopalatoplasty or UPPP who commonly still have retropalatal stenosis. Palatal advancement may be combined with other techniques to treat pharyngeal stenosis, such as expansion sphincter pharyngoplasty. Contraindications to palatal advancement include the presence of partial or complete cleft palate, velopharyngeal insufficiency, poor lateral pharyngeal wall mobility, preexisting dysphagia, or poorly vascularized tissue due to radiation or proximal palatal scarring. Patients who predominantly breathe via the oral route may note some constriction of the oral airway after palate advancement and may also need nasal procedures and/or tongue reduction surgery. Patients with very large palatal tori should have the tori removed before palatal advancement. If a patient wears an upper denture, the denture may need to be refitted. If a patient is likely to need future maxillomandibular advancement, palatal advancement may theoretically result in decreased vascularization and thus compromise healing.

Preoperatively, office transnasal fiberoptic endoscopy is performed to assess patients for candidacy. Drug-induced sleep endoscopy could also be performed to assess for a sagittal (anterior–posterior) axis of retropalatal collapse. The oral cavity is examined for the presence of central tongue grooving or scalloping of the tongue border, which reflects relative macroglossia. Patients with macroglossia may also need tongue reduction surgery. Imaging tests are not needed for selection of patients or preoperative assessment.

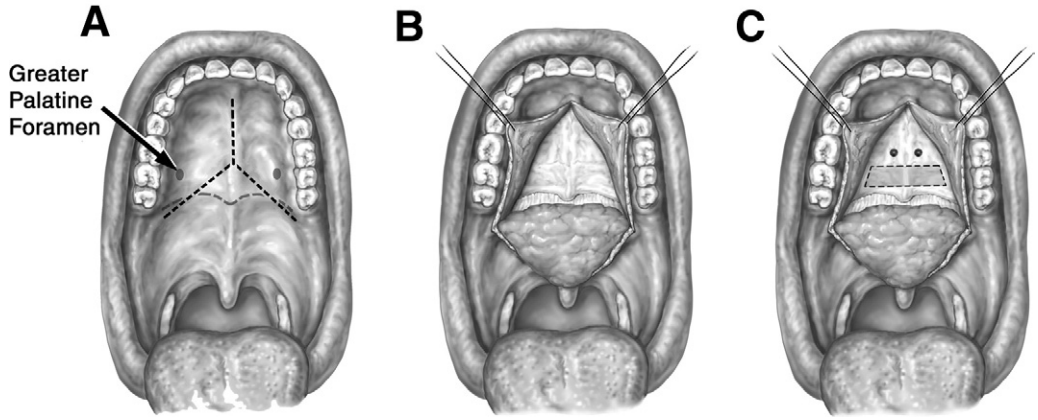

Figure 6 (A) Propeller incision with associated landmarks. (B) Lateral flap elevation, exaggerated for illustration. Flap may be secured with a suture for exposure. (C) Osteotomy site marked on hard palate. Distal hard palate segment is preserved. Drill holes for suture approximation are marked.

Preoperatively, optimization of the patient's medical status is obtained, given the increased cardiovascular risk in some OSA patients. Communication with anesthesiologist and surgical team is important to heighten awareness for airway and cardiovascular risks. Patients are treated with a multimodal regimen to diminish pain and reduce the narcotic requirement postoperatively.[11] The regimen includes pre- and postoperative intake of systemic steroids, acetaminophen, cyclooxygenase-2 selective inhibitors, and gabapentinoids, as appropriate, to reduce postoperative hyperalgesia. Antibiotics and topical disinfectants are used to reduce the bacterial load in the pharynx, which may contribute to pain. Tissue cooling and sucralfate are also used to promote analgesia. Patients are instructed to avoid denture wear, to eat a soft diet, avoid forceful swallowing, and to alert the surgeon if a palatal fistula is suspected.

Risks of palatal advancement include velopharyngeal insufficiency, globus, excess phlegm or dryness, and dysphagia. These risks are common to all palatopharyngoplasty techniques. Interestingly, velopharyngeal insufficiency is very infrequent, as compared with traditional UPPP. Palatal fistulas may occur and should be treated using an oral splint, fashioned by a dentist, to cover the fistula, facilitate speech, diet, and reduce bacterial contamination. Resuturing of the palatal wound in the office setting is also performed to facilitate closure, and suturing may be repeated as needed. Rarely, operative closure of the fistula may be needed.

Surgical procedure

Palatal advancement can be arbitrarily described as a series of steps. These include exposure, tissue removal, advancement, closure, and postoperative care.

Step 1 (Figure 6A): Exposure. The sites of the incision as well as greater palatine foramina are injected with local anesthetic with epinephrine for hemostasis and preemptive analgesia. The mouth is prepped with chlorhexidine or similar appropriate antiseptic solution. The procedure is usually performed in a modified Rose position using a Dingman or

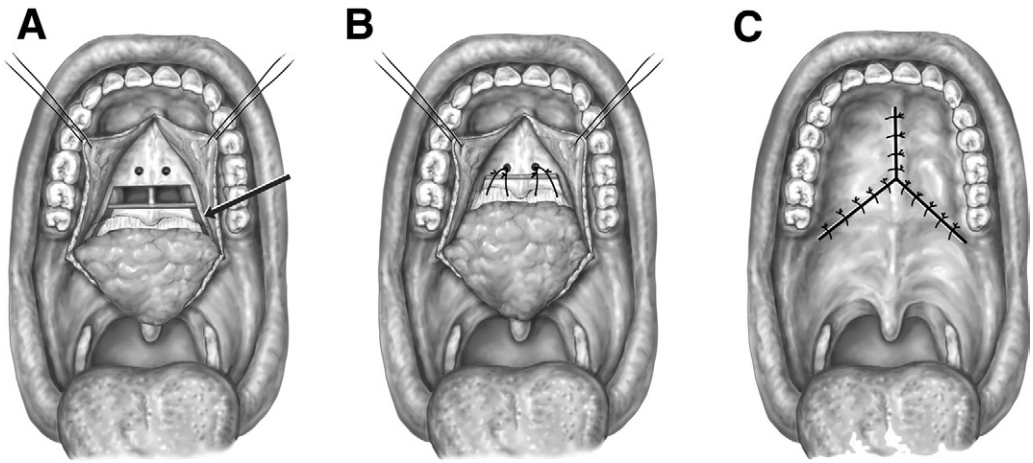

Figure 7 (A) A posterior osteotomy has been performed leaving a 1- to 2-mm rim of bone. The osteotomy is separated from the posterior nasal septum. Proximal drill holes are placed lateral to septum and medial to the inferior turbinates. The soft palate and hard palate are separated exposing nasopharynx, and lysis of tensor aponeurosis medial to hamulus is performed (arrow). (B) Sutures are placed through palatal drill holes and around the palatal osteotomy and into the tensor aponeurosis laterally. Posterior traction is used to advance the flap, and sutures are tied. (C) Mucosa is approximated with multiple interrupted sutures.

similar mouth gag. Good visualization of the operative site may be difficult to achieve, and the surgeon may need to use alternative vantage points. For some patients, the surgeon positioned at the side of the patient may be better than a traditional tonsillectomy approach. Landmarks used for the incision include the greater palatine foramen, junction of the hard and soft palate, the hamulus (maxillary tuberosity), and the junction of the palatine bone and maxilla where the palatal mucosa becomes significantly thicker. A finger is used to palpate the proximal hard palate where the mucosa is quite thin. Because the surgeon palpates posteriorly, a point where the palatal mucosa thickens can be felt (usually slightly anterior to the greater palatine foramen). This is the center point of the "propeller incision." From this point, the incision is carried anteriorly in the midline toward the alveolus. Two incision lines (right and left) are then directed posteriorly toward the tip of the hamulus (maxillary tuberosity). It is strongly recommended to leave several millimeters of mucosa between the incision and the alveolus to make closure easier at the end of the procedure. After the incision is made an angled elevator is then used to elevate flaps laterally and posteriorly to the margin of the bony hard and soft palate (Figure 6B). Hemostasis is achieved with bipolar cautery to minimize collateral tissue damage. Lateral flaps can be retracted with sutures placed in the thicker portion of the flap (careful not to tear tissues or to use self-retaining malleable retractors).

Step 2 (Figure 6C): Tissue removal. A 4-mm diamond drill (to reduce the risk of damaging the mucosal flaps with a cutting burr) is used to remove an approximately 1-cm width of hard palate. A small 1- to 2-mm strip of posterior hard palate bone is left attached to the aponeurotic segment of soft palate to preserve ligamentous attachments and create a much stronger wound closure. This osteotomized segment is separated from the septal bone medially and the alveolar bones laterally using heavy scissors or a small drill. Bleeding from the septal and nasal mucosa may occur, and pretreatment with a vasoconstrictor may be useful. Two through-and-through drill holes through the hard palate are created 4-5 mm proximal to the osteotomy site. These are lateral to the septum and medial to the anticipated location of the inferior turbinates.

Step 3: Mobilization. Electrocautery is used to incise the nasal mucosa, being aware that the posterior tip of the inferior turbinates is immediately adjacent, which can result in significant bleeding. The nasopharynx is now visualized. The palatal aponeurosis (previously referred to as the tensor veli palatine tendon) must now be incised. This is white band adjacent to the nasopharyngeal mucosa in the soft tissues of the palate. The aponeurosis is incised several millimeters medial to the hamulus (maxillary tuberosity). This avoids damage to soft tissue and vascular structures in the lateral nasopharyngeal wall, and by leaving the aponeurosis tightly adherent to the hamulus, eustachian tube function is preserved. Once the palatal aponeurosis has been incised, there is wide visualization of the nasopharynx and the eustachian tube orifices.

Step 4 (Figure 7B):. Advancement and closure. Zero Vicryl sutures on a UR-6 needle are passed blunt end first (to reduce bleeding from the inferior turbinates) through the proximal palatal drill holes in the nasopharynx. Two sutures are placed in each drill hole. Posteriorly, a suture from each side is around the bony osteotomized segment in the center of the soft palate and aponeurosis. Avoid including fibroadipose tissue of the soft palate, which will not structurally hold a suture. A suture form each side is also placed laterally and carefully including the palatal aponeurosis. Substantial force is exerted on the soft palate with swallowing, and failure to include the palatal aponeurosis likely increases the risk of postoperative fistula. Once all four sutures have been placed, the assistant places a blunt instrument behind the palate and holds it forward to reduce any tension while the surgeon ties the sutures.

Step 5 (Figure 7C): Closure. Excess fibroadipose tissue of the soft palate is trimmed, but mucosa is preserved to allow for a tensionless mucosal closure. Mucosal flaps are then closed with monofilament sutures. Significantly thick soft palate may require additional sutures to close a soft tissue dead space and prevent subsequent seroma formation with subsequent postoperative fistula.[12-16]

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