Feminization Laryngoplasty - Technique

Abstract

Objectives: Feminization Laryngoplasty is an evolving surgical technique with the aim to raise both the fundamental frequency of the voice and the resonant frequency of the vocal tract in male-to-female transgender patients. It is designed in an attempt to address possible shortcomings in quality, longevity, as well as complications of existing procedures. This paper explores the reasoning behind and the evolution of the Feminization Laryngoplasty procedure.

Methods: Feminization Laryngoplasty consists of removal of the anterior thyroid cartilage to collapse the diameter of the larynx with the added benefit of removing the protruding profile of the Adam's Apple more extensively than the existing procedure of "Tracheal Shave". Removing the anterior vocal cords shortens, possibly thins and allows further tensioning of the vocal cords with the goal of raising the comfortable speaking pitch. Shortening the false vocal cords narrows the supraglottis and may alter resonance. With the removal of the superior margin of the thyroid cartilage, the vertical dimension of the larynx is shortened and the larynx can be suspended higher in the neck via thyrohyoid elevation with the goal of shortening the pharynx and altering resonance towards more feminine overtones.

Feminization Laryngoplasty may be used as an approach to reattach and retighten vocal cords after the complication; vocal cord detachment, which may occur as a complication during a "Tracheal Shave."

Postoperatively the vocal cords may be tuned further with an office laser tightening procedure.

Results: Feminization Laryngoplasty surgically attempts to create a feminine voice quality in male to female transgender patients, as an alternative to existing procedures of anterior commissure advancement, cricothyroid approximation, vocal fold webbing and laser vocal fold tightening. Benefits include a generally well camouflaged incision, elevated comfortable speaking pitch, elevated lowest speaking pitch and resonance may be altered in the direction of female vocal quality.

Risks and limitations of the procedure include the need for an external incision, potential infection and airway compromise in the immediate postoperative period. Upper limits of the vocal range may be lowered and the upper range may have a tighter quality. Uneven tension may cause roughness of the voice requiring additional procedures. Comfortable speaking volume and maximum volume tend to be reduced.

Indexing keywords

Feminization, Laryngoplasty, pitch, transgender, voice

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Introduction

Once exposed to testosterone, typically during puberty, the thyroid cartilage enlarges, both increasing the internal luminal size of the larynx as well as altering the neck profile by visible protrusion of the Adam's Apple. The vocal cords elongate and thicken, lowering the comfortable speaking pitch and lowest vocal pitch. There is usually a reduction of the upper vocal range or at least a change in the quality of the upper vocal range since thicker vocal cords must be stretched tighter to produce the same pitch. The relaxed laryngeal position drops lower in the neck increasing the internal length of the pharyngeal chamber; a longer chamber selectively amplifying the lower notes.

In individuals identifying as female gender (whether genetically male, intersex or female), speech therapy or self-practice may result in learning to produce a desirable speaking vocal pitch and resonance, masking these changes induced by testosterone. These techniques utilize active compensatory muscle contraction of intrinsic and cervical muscles and require ongoing effort. Some individuals are successful in developing a habitual contraction, to the point of requiring conscious effort to lower their larynx and speak with their "male voice" while perhaps most others develop ongoing fatigue from these attempts at maintaining female pitch and resonance through tonic muscle contraction. Some individuals are rather unable to accomplish this task. Even when successful, some individuals remain fearful of letting their guard up for even a moment in a sensitive situation where a masculine voice would be inappropriate. As an ideal, after transition, comfortable speech would occur at a feminine pitch and with a feminine quality without having to think about contracting several muscles before every phonation.

The fundamental frequency of speech is one distinctive parameter in determination of a male versus female voice [1,2]. A number of pitch-altering surgeries have been pursued to address this frustration including cricothyroid approximation (CTA) [1 - 8], anterior commissure advancement [9]and vocal cord webbing [10 - 12].

CTA is one of the most common surgeries currently used to change the relaxed pitch of the voice. The normal action of the cricothyroid muscle is to lengthen the vocal cord [13]. The vocal quality produced by this increase in tension of the vocal cord is called falsetto. Bringing the thyroid cartilage and cricoid cartilage into approximation in the anterior midline, CTA surgery effectively sutures the cricothyroid muscle into a permanent position of contraction, although the degree is variable.

Some of the positive attributes of CTA surgery include the following. It is relatively easy to perform the surgery with the anatomy located very close beneath the skin. Surgeons inexperienced with the procedure can perform it relatively well.

There is minimal discomfort with the procedure and it may be performed under local anesthesia. The patient may speak during the procedure if the surgeon has a desire to attempt to "tune" the pitch during the procedure, although for many "CTA surgery is typically performed with intentional hyper-elevation of pitch in anticipation of gradual relaxation of the induced vocal fold tension over time" [14]. Because it is relatively easy to perform, relatively safe from surgical complications and can be performed in a relatively short time, surgical costs associated with the procedure are low.

I began performing CTA surgery in 2001 for male to female transgender patients wishing to speak comfortably at a higher pitch in day-to-day conversation. I reviewed results on 23 patients in 2003 for a presentation (Thomas,J.P. Cricothyroid approximation & other phonosurgical proce-

dures to alter the transgender voice. Biennial meeting of the Harry Benjamin International Gender Dysphoria Association, Inc. (HBIGDA), September 12, 2003, Ghent, Belgium). I noted that in aggregate, there was elevation of the comfortable speaking pitch by 7 semitones, although this ranged from a lowering of the speaking pitch by two semitones in one patient to an elevation of pitch by 18 semitones in one patient. The range was wide and seemingly unpredictable. To most patient's relief, individuals also lost an average of 9 semitones from the bottom of their speaking range, providing a speaking pitch not at risk for a sudden drop in pitch.

Significant issues were noted with the CTA procedure. Some patients experience an initial pitch elevation that fades back to a baseline pitch over a few months, ultimately experiencing no permanent change in their voice at all. This occurred in about one third of patients despite vocal cords that remained visibly stretched on endoscopy. Neumann et al also noted about one third of patients had a neutral pitch and about one third failed to gain in pitch [15]. They appeared to have lost pitch elevation by losing internal tension. I noted that the cricothyroid suture was not the cause of failure to raise pitch based on observations of patients of my own and others that I attempted to surgically revise. During attempted surgical revisions on my own and other surgeon's patients with this complaint, the cricothyroid space remained ablated, typically with the cricoid and thyroid cartilage fused in the anterior midline. Even with various suturing techniques including metal sutures, bolstered sutures, single or multiple sutures, none of the sutures had pulled out.

Another problematic issue was that many patients with successful pitch elevation spoke with an unnatural, hyper-elevated pitch ranging from an extreme falsetto to a mild falsetto quality of their voice. For some surgeons, "CTA surgery is typically performed with intentional hyper-elevation of pitch in anticipation of gradual relaxation of the induced vocal fold tension over time" [14].

Some of my patients describe it as a "gay male" sound.

An uncommon problem was observed related to the cricothyroid joint. The joint appears to become so fixed, perhaps subluxed, such that an individual may almost completely lose the ability to change pitch and volume at all, leaving them with a monotonal voice (primary author's observation).

At best, I reasoned that the post CTA patient forfeits the use of her cricothyroid muscle so all pitch changes must now be produced by tensioning the thyroarytenoid muscle. Because I felt these issues were significant vocal compromises for the patients, I looked for an alternative approach that would raise the comfortable speaking pitch.

There are various types of lasers and various modalities for using lasers on the vocal cords. One type of laser treatment, LAVA, attempts to increase vocal pitch through a thinning and tightening of the vocal cords. Increases in fundamental frequency with this technique tend not to be as large as with other surgical methods [14]. One advantage is that no external incision is required. In one of my patients whose pitch spontaneously returned to the masculine range after CTA, the addition of the LAVA procedure brought her comfortable speaking pitch back up toward the female range again temporarily. So it is possible that some combination of procedures might be beneficial. See also [16].

A proposed fundamental frequency range for adult females is 145-275Hz (D3-C#4) and for males is 80-165Hz (D#2-E3) [16]. This leaves an area of overlap from 145-165Hz (D3-E3) where fundamental frequency alone might not be sufficient to determine the sex of a patient. This is important as transgender patients with Fo as high as 181Hz have been perceived as male. "It appears

that it is the interaction between Fo, Fo range, intonation and resonance that ultimately determines the perception of the speaker as female" [17]. Addressing these components as complements to each other would represent a more desirable approach to voice modification compared to fundamental pitch change alone.

Resonant frequency also affects the gender perception of voice. This is especially true in the gray area where normal male and female speaking pitches overlap [18]. The resonant frequency is inversely related to the length of the resonant tube, the pharynx [19]. Speech therapy techniques have been used to modify the mouth opening and tongue placement [17]. Gunzburger noted that when comparing transexuals' male vs. female voice the resonance patterns change [20]. He hypothesized that this was accomplished by practiced manipulation of oropharyngeal shape and the elevation of the larynx [2, 20]. Elevation of the larynx enables higher resonant frequency of the pharynx, as the length of the resonant tube is decreased [21].

In transgender patients particularly adept at creating a female voice quality, I noted an ability to maintain with muscle tension two pharyngeal parameters: elevation of the larynx and narrowing of the pharynx. Based on a personal communication with Robert Bastian discussing this idea, I began to suspend the larynx higher in the neck (thyrohyoid elevation component). This might address one of the parameters, length of the pharyngeal chamber, leaving to the patient to address the diameter of the chamber with muscle contraction if possible.

I have tried to reduce the diameter of the pharyngeal chamber in one patient but I have not worked out a reliable technique to accomplish narrowing. Perhaps I removed an insufficient amount of tissue.

Somyos Kunachak in Thyroid Cartilage and Vocal Fold Reduction [22] proposed an open laryngoplasty to alter pitch. This procedure reduced the size of the larynx to a more female size in its cross sectional dimension and shortened the length of the vibratory vocal fold. It possibly tensioned the vocal fold. It preserved the use of the cricothyroid muscle. Perhaps it thinned the vocal folds. Based primarily on this article, I began to perform what developed into a procedure termed Feminization Laryngoplasty or as my first patient called it, "FemLar."

Pre Operative

After an appropriate history, the patient's voice is recorded reading a standardized passage (Man's First Boat). Comfortable speaking pitch, attempted best female voice, vocal pitch range, maximum and minimum volumes, maximum phonation time and vegetative sounds are recorded. The vocal cords are then visualized and video recorded with flexible laryngoscopy including stroboscopy at a variety of pitches and volumes. Alternatives to surgery and the possible risks are discussed. Patients attend a one-hour voice education discussion with a speech therapist prior to surgery.

Surgery

Location: All surgeries have been performed in a Medicare certified, outpatient surgical center. The procedure is typically two hours long.

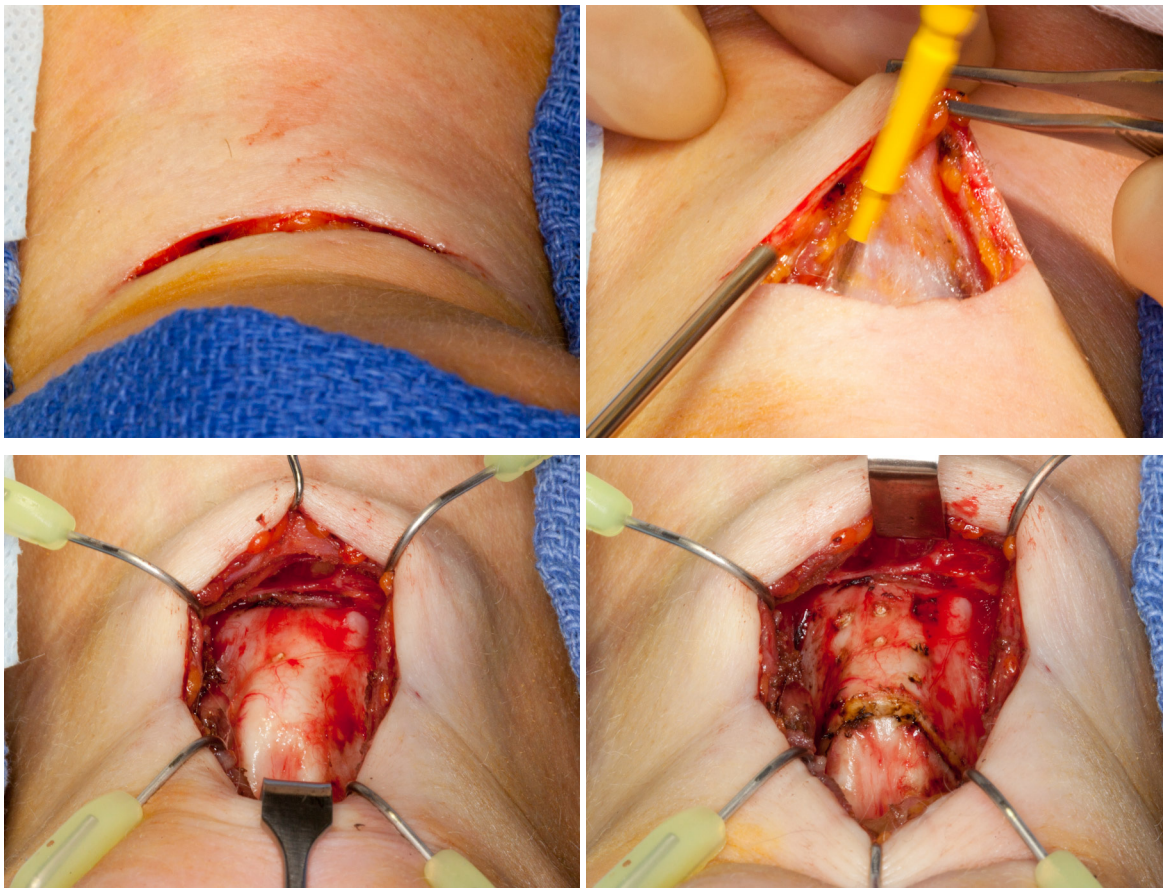
Anesthesia: The procedure is performed under general endotracheal anesthesia using a 6-0 endotracheal tube.

Antibiotics: All patients are given gentamicin and clindamycin at the beginning of the case if there are no drug allergies to either medication. 600 mg of clindamycin is administered IV over

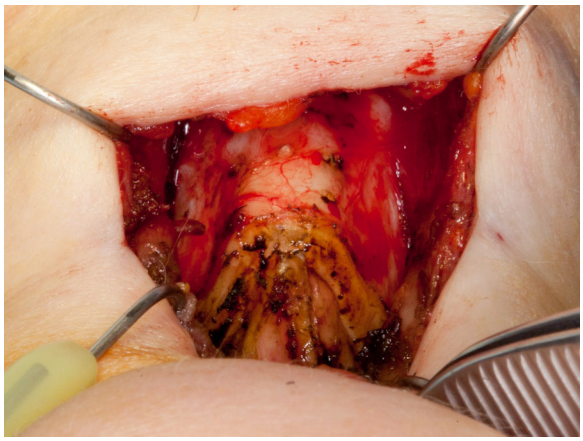
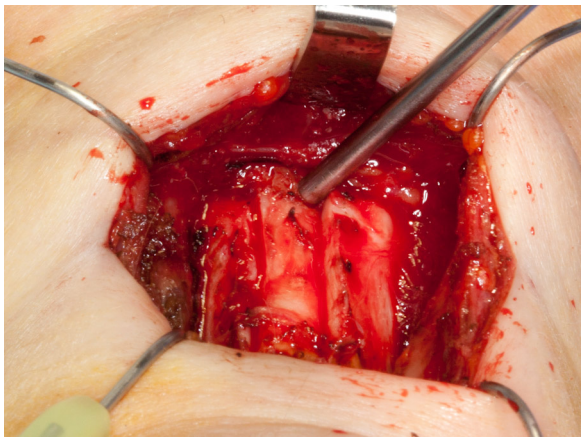
10 minutes and 80 mg of gentamicin is placed in the first liter of IV fluids. (Since this cohort of patients, I have changed to clindamycin and Claforan at the time of surgery with 7 days of post-operative oral therapy with either cefuroxime or levofloxacin). Typically the liter of fluid had been administered around the time of entry into the airway. The wound is irrigated with normal saline containing 100,000 units per liter of bacitracin prior to closure.

Steroids: 10 mg of dexamethasone are given intravenously at the beginning of surgery. Oral prednisone or methylprednisolone are given in selected cases if significant swelling develops post-operatively.

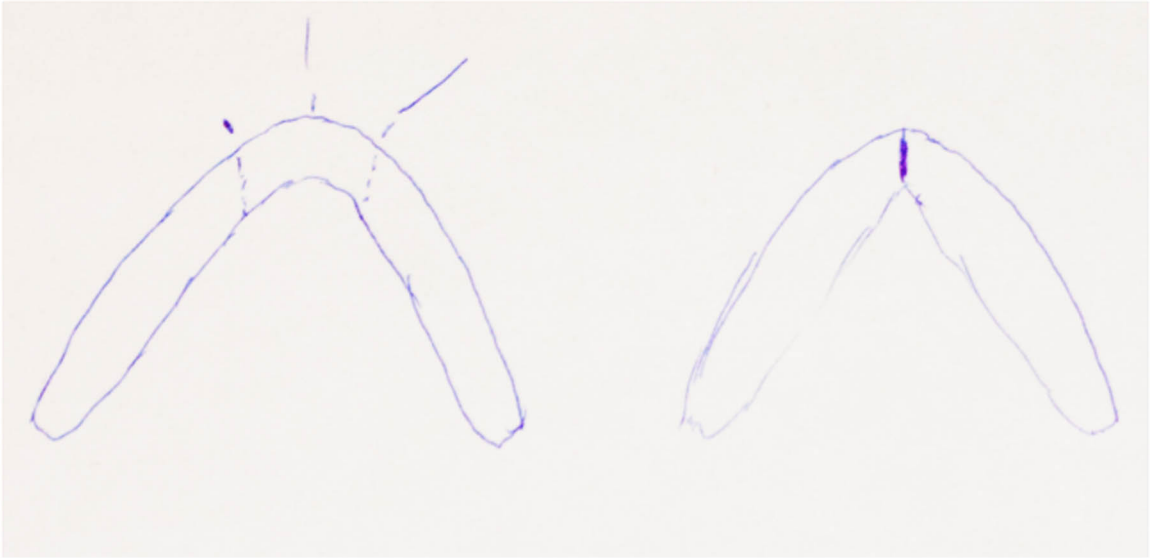
Technique: (All photos are taken from the perspective of the anesthetist at the head of the table.)



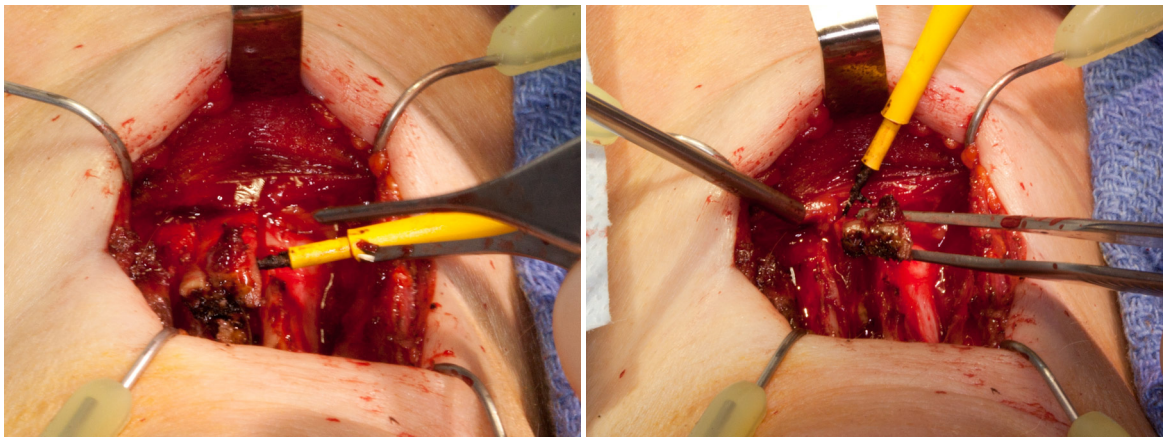
An approximately 5 cm incision is placed in or parallel to a skin crease directly in the midline and flaps developed at a level beneath the platysma. Strap muscles are separated in the midline exposing anatomy from the hyoid bone to the upper cricothyroid membrane. The midline is marked with a Bovie cautery and secondary marks are placed 5 to 7 mm lateral to the midline on each side. I have also marked the upper incision to remove the upper alae of the thyroid cartilage.

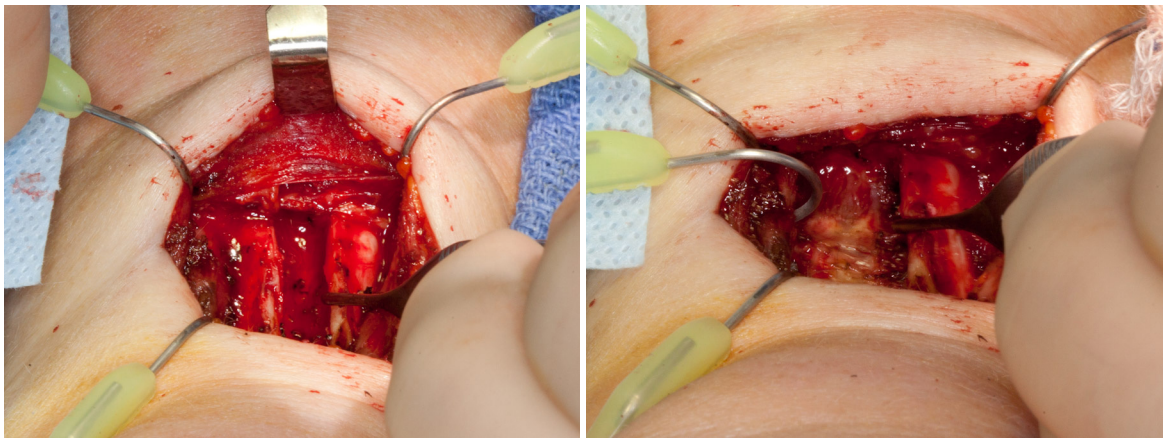
If a thyrohyoid elevation is planned, the upper portions of the thyroid cartilage may be removed at this point (or later after division of the thyroid cartilage in the midline). The thyroid cartilage is divided vertically with an oscillating saw about five to seven millimeters on either side of midline with the saw kerf removing about one additional millimeter of cartilage. The goal is to narrow the internal aperture of the laryngeal glottis by collapsing the thyroid alae medially.



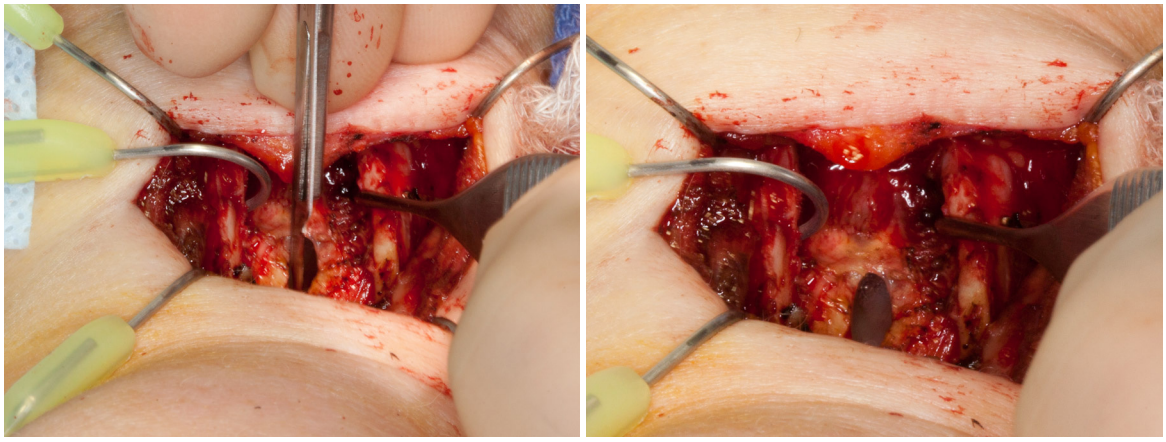
Beveling the cuts: Cuts placed at a 90 angle to the cartilage allow only the inner thyroid lamina to approximate. The inner lamina is more contoured than the outer lamina with an internal bulge inferior to the vocal cords. A 90-degree cut thus prevents an airtight closure unless these contours are then removed with a cutting burr. By comparison direct saggital cuts allow only the outer lamina to approximate when the alae are collapsed back into the midline. Consequently, I attempt to bevel the cuts between these two planes to allow complete, airtight closure of the new anterior larynx in the midline.



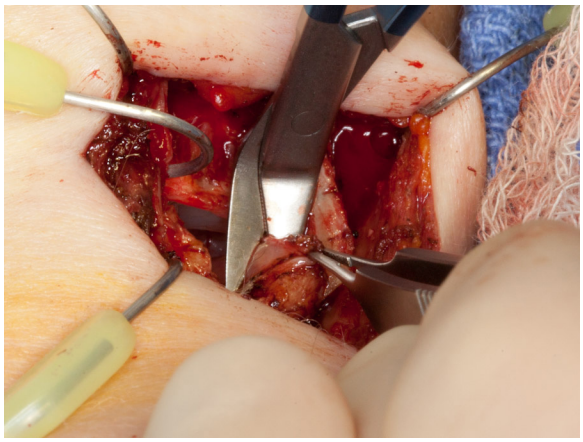
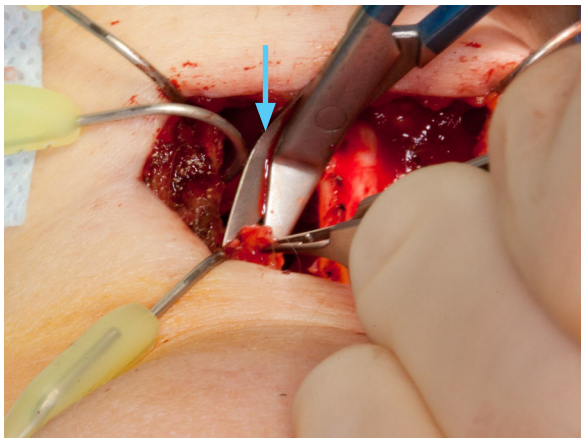
With electrocautery, the strip of anterior thyroid cartilage is elevated away from the soft tissue and removed. This removal of the vertical anterior thyroid cartilage segment will both narrow the internal laryngeal aperture and very effectively remove the Adam's Apple contour (more completely than a ."tracheal shave"). The airway is not typically entered, though if it is, penetration usually occurs in the thinnest area, which is just superior to the anterior commissure.



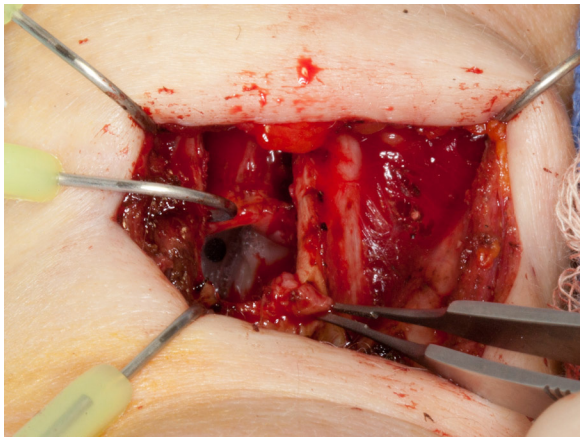
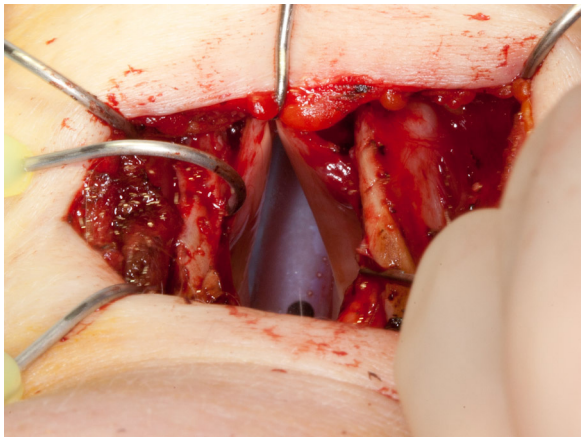
The thyroid alae may be retracted laterally for a better view of the internal glottis. The vocal cord anterior ligaments are identified (blue arrow).



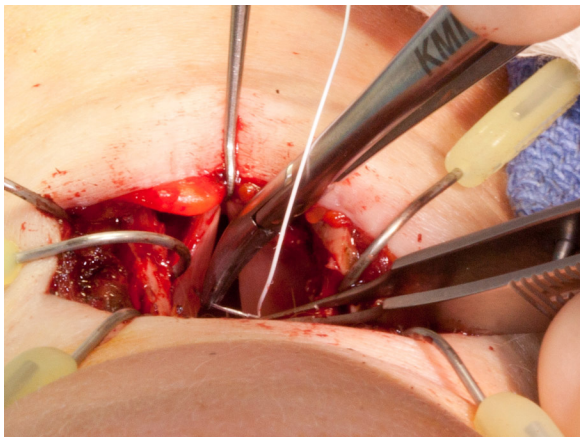
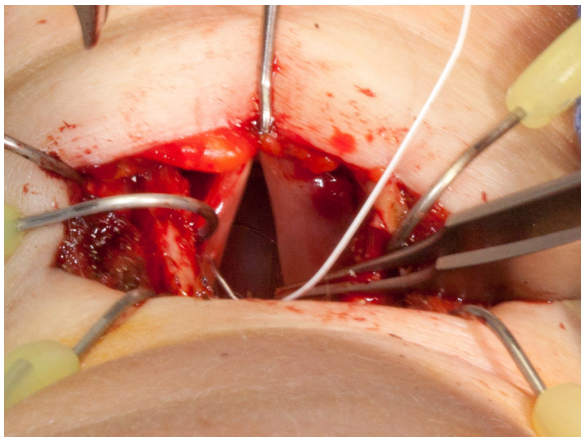
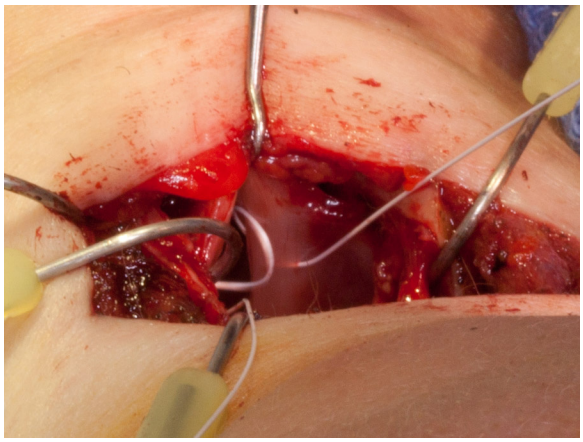
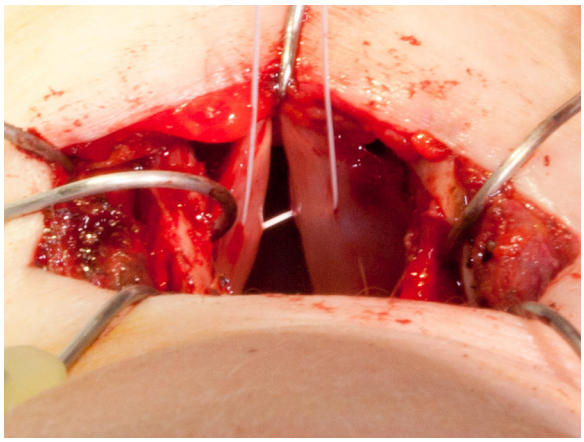
The airway is incised just superior to the anterior commissure. I extend this midline incision superiorly through the anterior commissure of the false vocal cords for a view of the endotracheal tube and the true vocal cords from above.

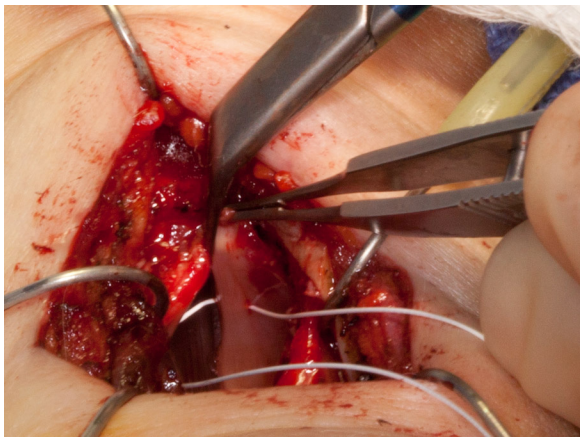
I remove approximately the anterior 1/3 of each false vocal cord, likely including the saccule. This reduces the diameter of the supraglottis after surgery. During surgery, this also provides an improved view of the true vocal cords and more space to manipulate needles within the larynx.

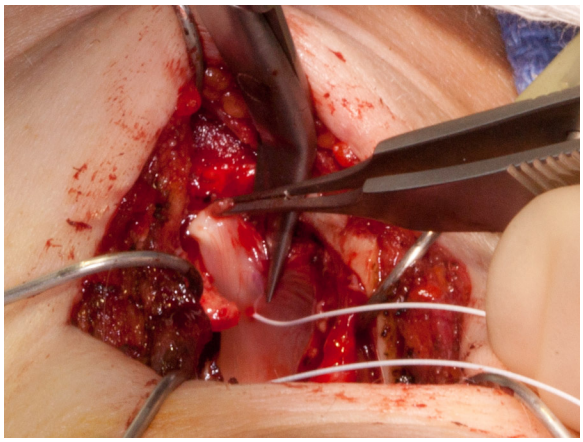
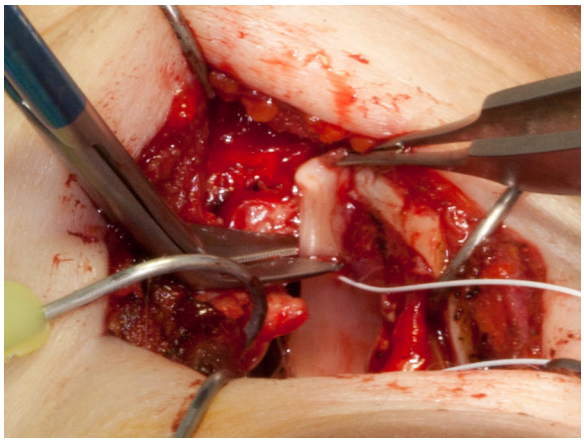
I prefer to maintain the anterior glottic ligament intact so that I can pull symmetrically on the vocal cords with a hook. I assess how much of the anterior vocal cord needs to be removed in order to collapse the thyroid alae back into the midline while maintaining tension on the vocal cords.

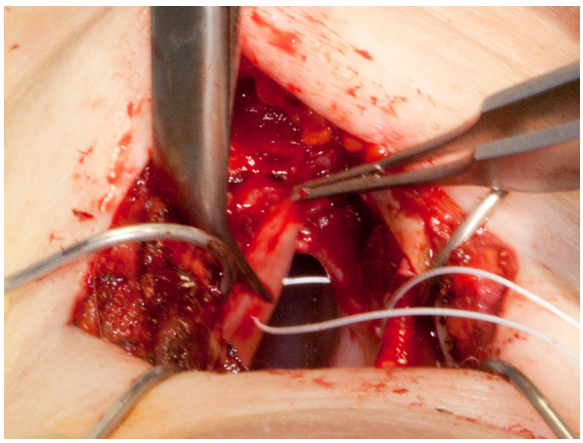
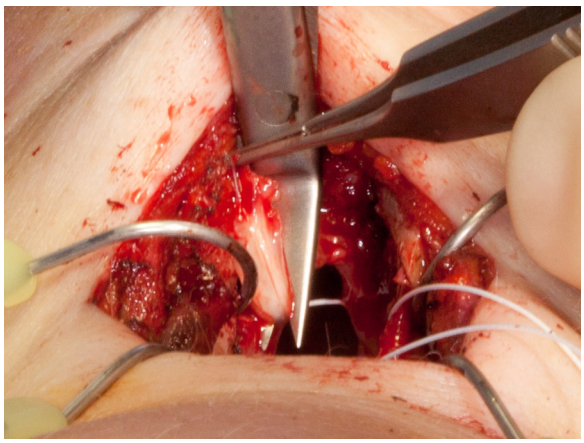
As I stretch them, I use one half of a double-ended 4-0 polytetrafluroethylene (Gore-Tex) suture to mark the perceived 50-60% location along the membranous vocal cords as measured from the anterior commissure. I try to include the vocal ligament in this suture to maintain not only a symmetric length to the neo-vocal cords, but also to maintain the vibratory margins vertical symmetry. My anticipated goal is to remove about 40 – 50% of the anterior membranous vocal cord. With removal of the anterior thyroid cartilage, the anterior-posterior dimension of the larynx will be smaller, so more membranous vocal cord must be removed to raise pitch than in a straight thyrotomy where only a small amount of vocal cord resection will raise pitch to some degree.




I divide the anterior commissure, attempting to minimize the length of the incision inferior to the vocal ligaments. My goal is to keep the inferior extent of the excision beneath the lower boundary of the thyroid cartilage. If the subglottic incision continues beyond the inferior edge of the thyroid cartilage into the cricothyroid membrane, it is more difficult to obtain an airtight closure.

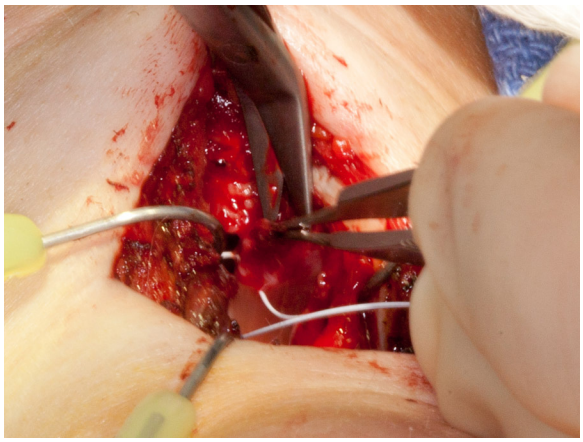



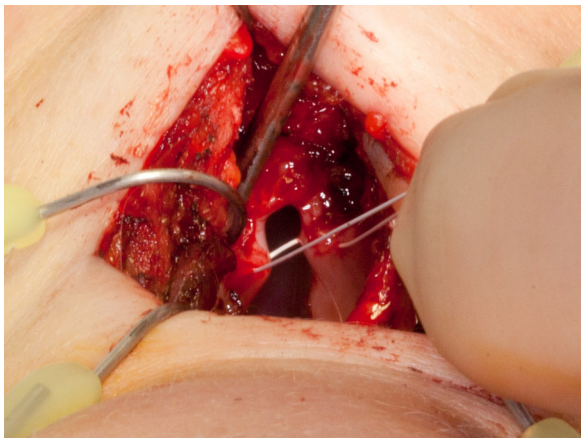
While tensioning each cord by grasping the anterior vocal ligament, right-angled scissors cut through the membranous cord. The mucosal cuts are beveled from lateral to medial. At the lateral aspect the cut is at the edge of the inner lamina of the thyroid cartilage. Medially the cut exits the cord just anterior to the marking suture. The mucosa, vocal ligament and the thyroarytenoid muscle are included in the removal.

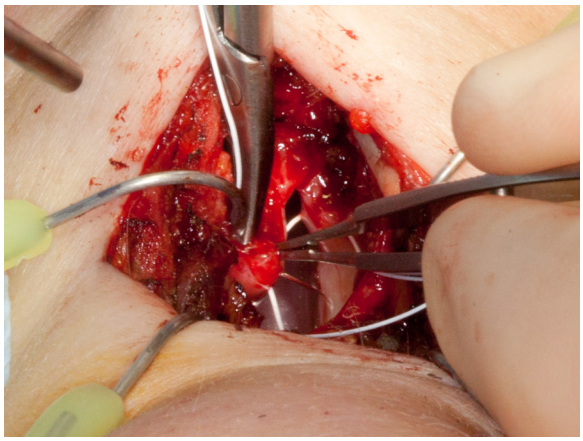
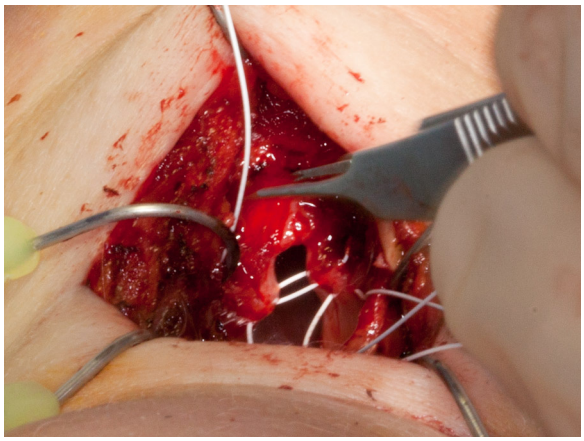
An identical amount is removed from the opposite vocal cord.

The cut edges of the thyroid cartilage are laid back together into their future position to check first for accurate coaptation. The cartilage is typically thicker just inferior to the attachment of the vocal cords. If tight closure is precluded by an inappropriate saw angle or because of any variation of thickness in the cartilage, these are removed or adjusted with a burr at this time.

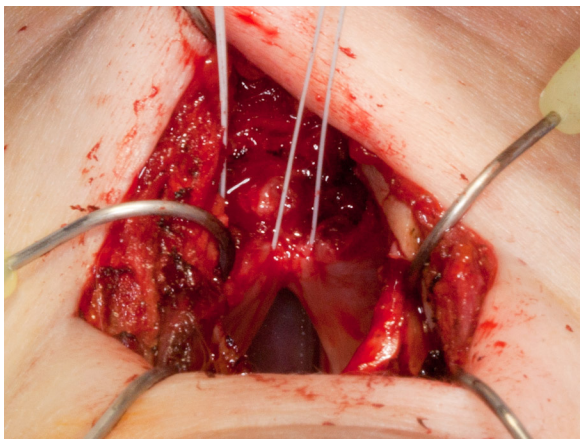
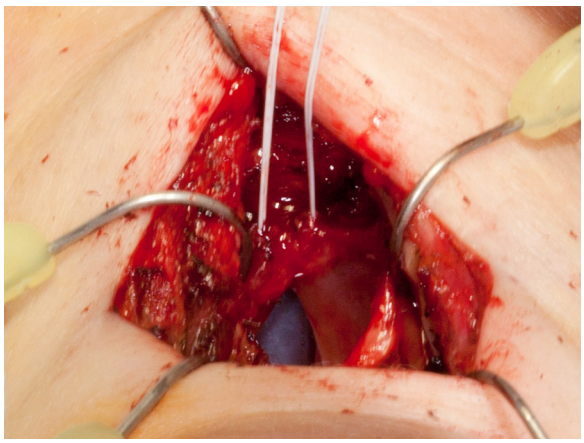




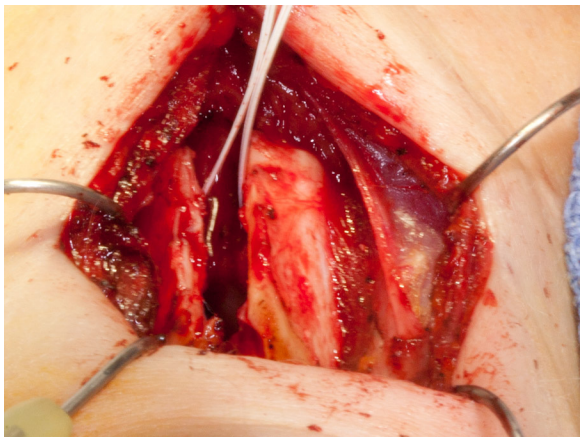
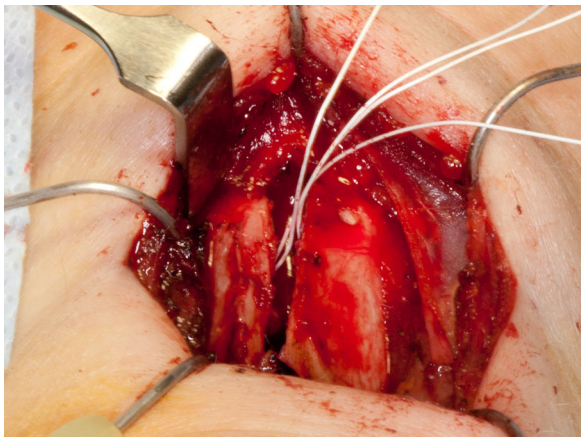
Secondly, the vocal cords are stretched as the thyroid lamina are brought back together to verify they are not too long to be placed under tension when secured against the inner thyroid lamina. If they will not be under adequate tension, then more vocal cord can be removed. At times, the issue seems to be too much tissue bulk. I then grasp the central thyroarytenoid muscle, place it on a stretch and remove or debulk some additional muscle, typically nearly the anterior half of the thyroarytenoid muscle.

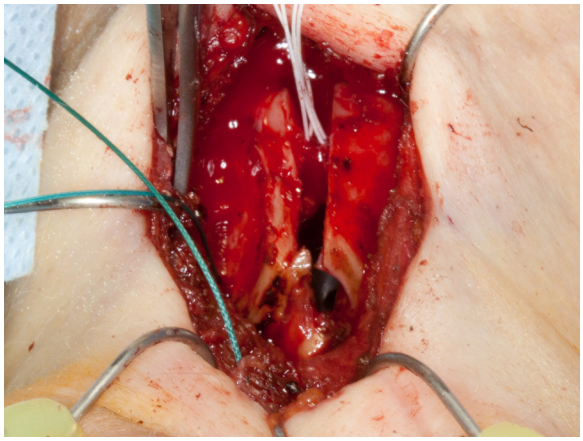
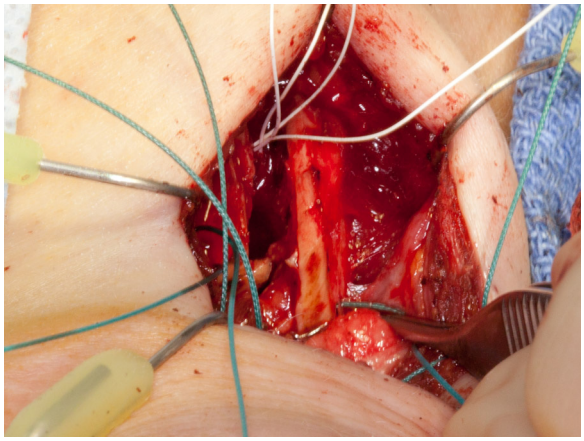
Anterior commissure reconstruction: Using a Gore-Tex suture, I place a horizontal mattress suture into the vocal cords. The needle enters the left thyroarytenoid muscle, passes through the vocal ligament (which feels slightly dense) and includes about 1 mm of medial margin vocal cord epithelium. I attempt to exit at what I perceive to be the upper vibratory lip of the membranous vocal cord. This passes into the opposite cord in a similar location beginning with the vocal cord epithelium and passes out through the thyroarytenoid muscle. I re-pass the needle back following a path about 1 mm inferior at what I perceive will be the new inferior vibratory lip of the membranous vocal cord. Both ends of this first suture exit the left thyroarytenoid muscle.

If I pull on the marking suture, I can visualize the neo-vocal cords (Left photo). I remove the Gore-Tex marking suture, reusing it, passing it in opposition using a similar pathway beginning with the right thyroarytenoid muscle. At the conclusion, both ends of one suture exit the left vocal cord and both ends of the other suture exit the right vocal cord. Pulling on these brings the new anterior commissure together.

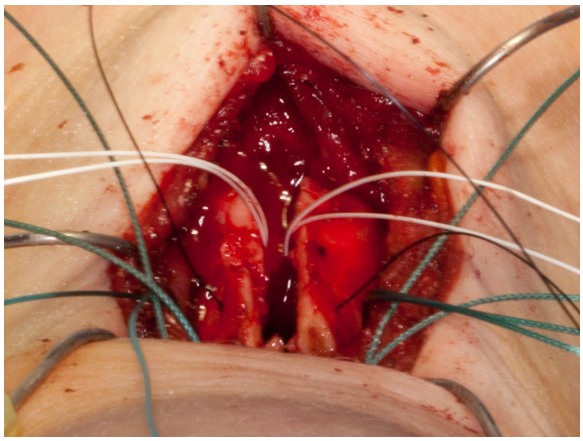
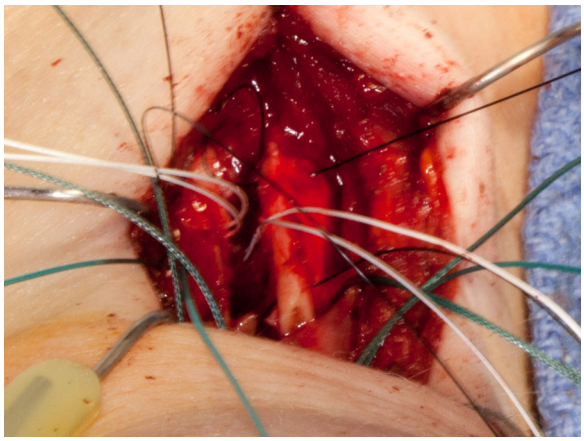
One reason that I use Gore-Tex is that when the thyroid alae are brought back together, the slipperiness of the Gore-Tex allows it to slide between the cartilage.

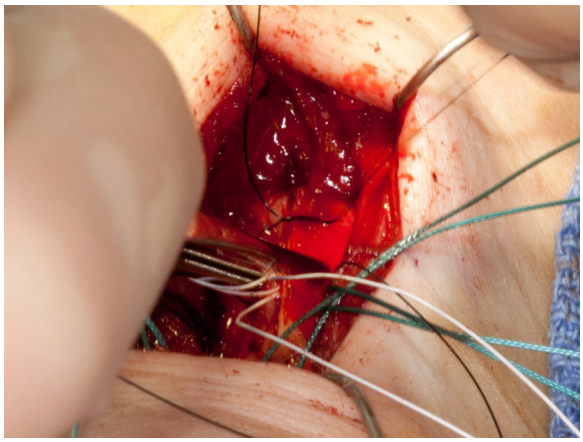
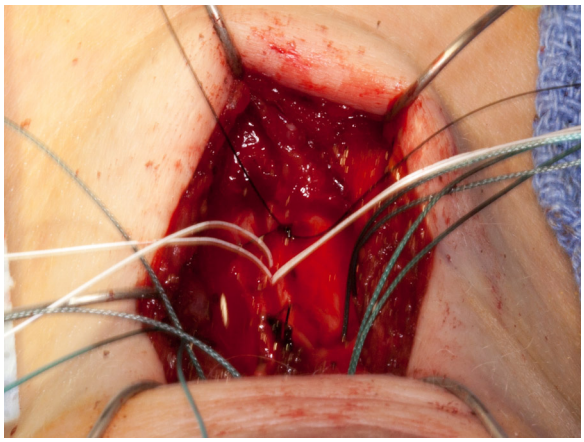
Thyrohyoid elevation: Muscles are elevated from the anterior inferior half of the hyoid bone with electrocautery. Strap muscles are divided at their insertion along the inferior edge of the hyoid bone for 15 mm either side of midline.

Closure: For closure of the thyroid cartilage, two, 1-mm holes are drilled in the new anterior edge of each thyroid cartilage, one inferior at the level of the subglottis, one superior at the level of the false vocal cords. Each hole is angled toward the midline internally. To create the thyrohyoid elevation, two additional holes are placed along each superior border of the thyroid cartilage where the upper wings were removed. The softer the cartilage, the further from the upper cut edge of thyroid cartilage I place these holes to avoid tear-out later when tightening. Four holes are drilled into the hyoid bone, two either side of midline. These are angled slightly inferiorly to allow passage of the large needle on 0-Ethibond sutures.

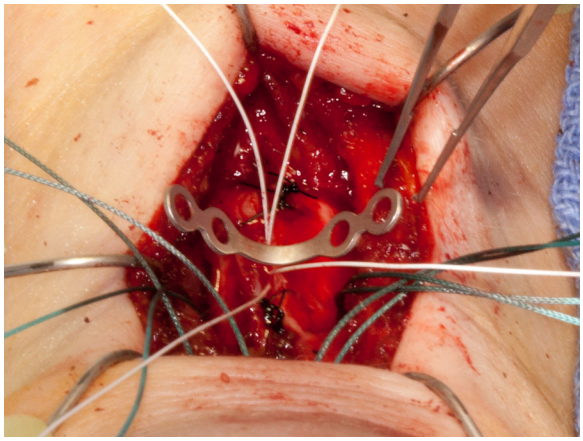
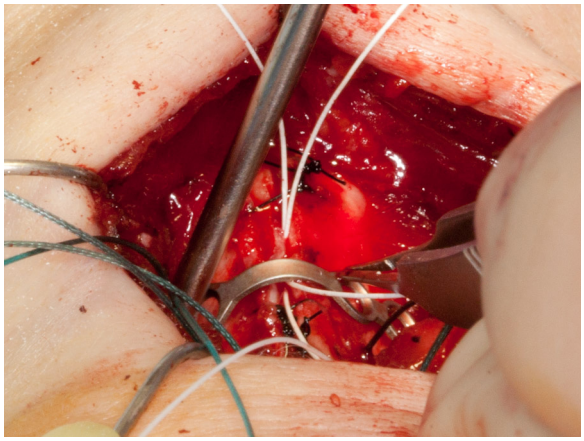
Four braided, 0-Ethibond sutures are individually passed through each hole in the superior edge of the thyroid cartilage and passed through a corresponding hole in the hyoid bone. No sutures are tied yet.

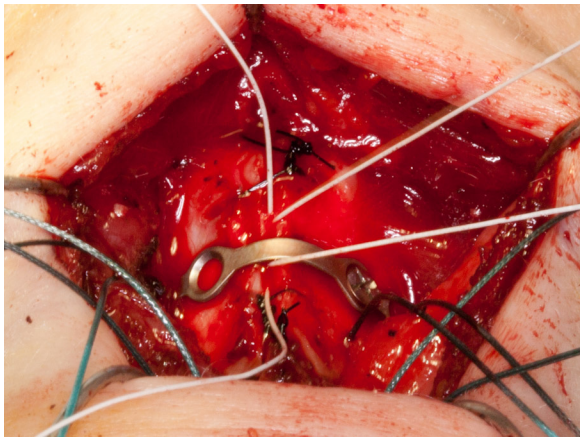
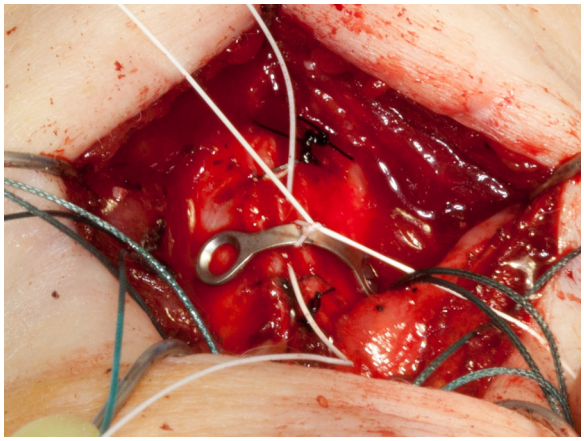
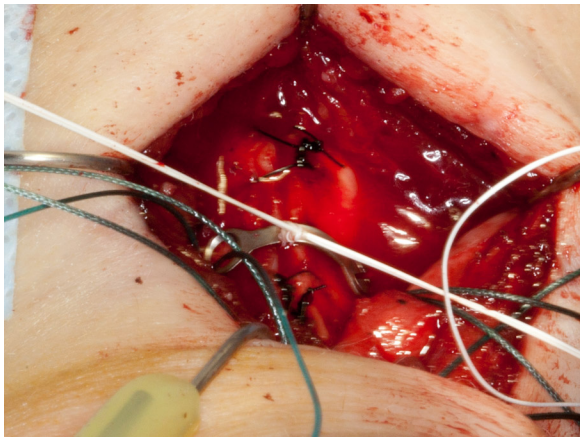
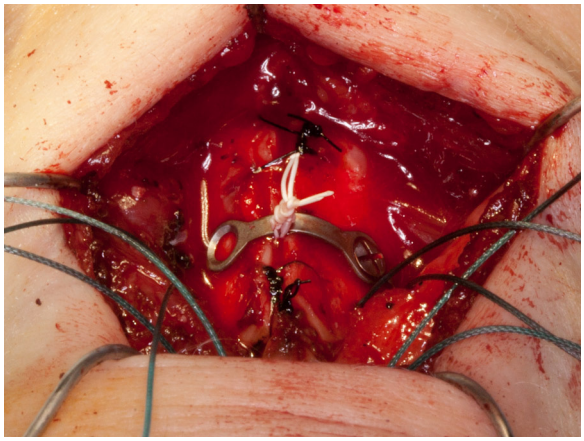
A 4-0 nylon or monofilament polygalactate??? suture is placed through the upper holes in the superior thyroid cartilage and internally includes the cut edges of the false vocal cords with the intent of pulling this up against the inner thyroid lamina during closure. Another 4-0 nylon suture is passed through the inferior holes and includes the cut edge of the subglottic mucosa, again with the intent that the mucosa will reattach to the inner thyroid perichondrium and that there will be an airtight seal in the immediate postoperative period. I leave this needle attached temporarily.

With all sutures in place, closure commences by bringing the cut edges of the thyroid cartilage together. The lower nylon suture is tied while an assistant squeezes the thyroid cartilage alae together with a forceps (above left photo). The upper suture is then tied securing the thyroid cartilage. With the needle still on this upper suture, I pass the needle through the tissue near the base of the epiglottis at the superior edge of the thyroid cartilage and secure it to the thyroid cartilage.

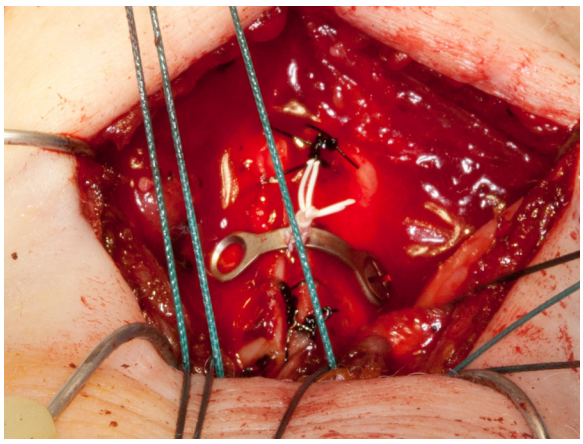
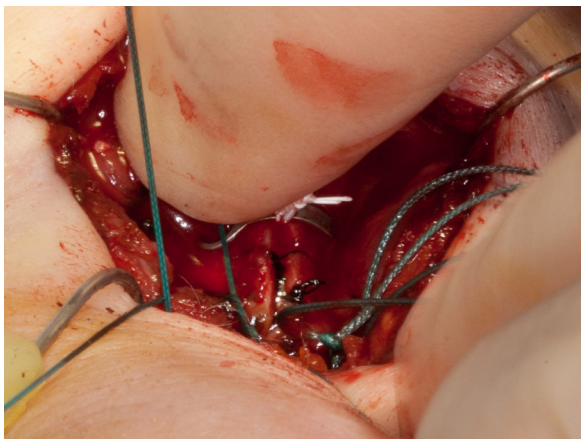



A 4-hole, dogbone shaped plate is bent to the shape of the newly angled anterior thyroid cartilage. It is placed preferably at the same level as the original attachment of the anterior commissure. I prefer self-tapping screws, which are placed bilaterally.

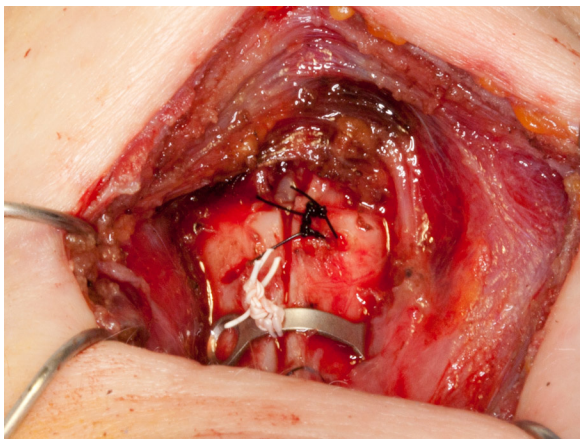





At this point the slipperiness of the Gore-Tex suture presents it's advantage, the ability to slide between the coapted edges of the thyroid cartilage. The Gore-Tex sutures are tightened and tied around the plate to pull the anterior commissure against the inner thyroid perichondrium. I have tried unsuccessfully to monitor the tensioning during this portion of the procedure with a flexible

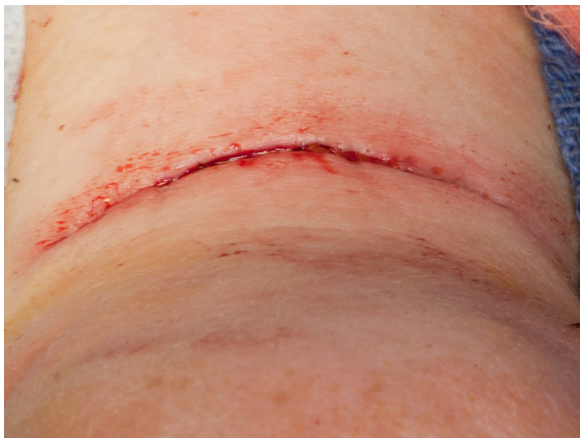
endoscope, but with the patient paralyzed, the soft tissues of the pharynx and larynx collapse onto the end of the endoscope precluded an adequate view of the glottis during the tightening.

The 0-Ethibond sutures are then tightened and tied, pulling the larynx superiorly in the neck. Typically the thyroid cartilage does not quite reach the hyoid bone.




The wound is irrigated with saline solution containing Bacitracin. The strap muscles are reapproximated and can be slightly plicated, pulled superiorly and reattached to the hyoid bone under some tension. Subcutaneous tissues are closed with 4-0 Monocryl.




The skin is closed with a running subcuticular suture, either 4-0 Monocryl. I place some form of cyanoacrylate on the skin.

A nasogastric tube is passed momentarily into the stomach and the contents aspirated. She is extubated deep and awakened.

Post Operative

Surgery is performed as an outpatient. Each patient is discharged after approximately one-hour into the care of a friend, family or a professional caregiver. Because of the general anesthetic, she must remain with someone for the first 24 hours postoperatively. Most stay in a nearby hotel of their choosing. Postoperatively each patient is examined with flexible laryngoscopy every day for three days. I see them again six days postoperatively and then she is free to return home if there are no complications.

Two weeks of complete voice rest are suggested. Pain is typically fairly minimal (though individually variable). A narcotic is prescribed for use as either pain or cough suppression. My postoperative instructions include instructions to avoid coughing. Nothing heavier than 10 pounds is to be lifted for one month. Other forms of straining, such as Valsalva maneuver, are strongly discouraged. I ask that she not be electively intubated for a period of three months. If intubated for general anesthesia she should request a number 6 endotracheal tube be used.

Acoustic data is taken from patients who subsequently return for scheduled follow-ups beyond the 2-week window. Voice samples are also accepted from patients who complete a recording by reading a voice analysis script. Recordings have been accepted on a wide range of media including computer files, video hi-8 tapes, cassettes, microcassettes, CD's and DVD's. Quality and background noise is variable. I have utilized software with Skype if the patient does not have recording capabilities, although cell phones and Skype seem to have automatic volume dampening that hampers assessment of some of the vocal parameters.

Caveats and thoughts

Anesthesia: My initial FemLar procedure was performed under local anesthesia. Although this is a feasible approach in terms of minimal pain during and after the surgery, the seeming risk of tearing the vocal cords while suturing them, if the patient tries to speak at an inappropriate moment, seems to outweigh the benefits of this approach. After the first patient, general endotracheal anesthesia was used largely to prevent vocal cord movement at an inappropriate time.

Dividing the cartilage: The thyroid cartilage is not calcified in some young patients and a knife may be used. Over a number of patients, I placed the cuts further and further laterally trying to further narrow the larynx, until in one patient, after removing 10 mm either side of midline, I could not approximate the inferior cut edge of the thyroid cartilage. The upper edge of the cricoid cartilage lies internal to the lower thyroid cartilage and the external diameter of the cricoid cartilage precluded complete closure.

Currently, the vertical incisions in the thyroid cartilage are generally placed about five to six millimeters either side of the midline. The amount removed varies with the perceived size of the thyroid cartilage. In very large thyroid cartilages and in cartilages with a very acute anterior angle the vertical thyroid cartilage incision tends toward seven or eight millimeters from the midline. In

small or very flat thyroid cartilages, perhaps only five or six millimeters are removed. At the typical beveled angle, in the average person, this removed piece of cartilage measures about ten millimeters in width across the outer table of the thyroid cartilage and about five millimeters in width on the inner table. The width or kerf of the saw blade itself is about 1 mm.

Revisions: Revisions are possible. In my first patient I conservatively removed additional vocal cord over three surgeries until we reached the pitch that she desired. I presently consider about 50% of membranous cord to be the appropriate amount to remove.

Prior CTA surgery: If a patient has had a prior CTA surgery, the cricoid and thyroid cartilage are typically fused. Even if they can be pried apart or even if they are sawed apart, in my experience, the cricothyroid joint has typically been immobilized long enough that the joint is non-functional. The cricothyroid muscle can no longer modify the vocal cord length. Dissecting apart this fusion sometimes lowers the pitch back into a male speaking range: certainly not desirable in most cases. Consequently, if there has been a prior cricothyroid approximation, I now leave the approximation intact. I utilize a midline thyrotomy division and do not remove any additional thyroid cartilage. The cricothyroid fusion limits opening of the thyroid cartilage and surgical exposure. I try to gain additional pitch elevation solely through removal of anterior membranous vocal cord and typically remove about 20% of the length.

Taking apart a cricothyroid fusion from a prior CTA however, may not be a reliable way to lower the pitch, again because of cricothyroid joint fixation. There is an uncommon patient wishing to return to a lower or male speaking pitch. If after taking apart a cricothyroid fusion under local anesthesia, there is no or insufficient pitch drop, I place two vertical thyrotomy incisions and remove one to 3 mm of cartilage from one or both sides which drops the tension in the vocal cords.

This issue of cricothyroid joint fusion is also the reason I discourage "trying the CTA surgery first". The CTA procedure causes loss of use of one of the most important muscles for changing pitch. The postoperative CTA patient has only the thyroarytenoid muscle remaining to change pitch. The postoperative FemLar patient has both a shortened thyroarytenoid muscle available as well as a cricothyroid muscle available to alter pitch.

Dividing the vocal cords: In early cases, I divided the anterior commissure early in the procedure so that I could widely open the larynx for a view. The very first time I cut the membranous vocal cords, the mucosa contracted all the way back to the vocal process, an unsettling maneuver that makes the vocal cord seem to disappear. It is possible to re-grasp the mucosa and the vocal ligament. However, resecting the anterior vocal cord one at a time seemed also to be a possible contribution to the likelihood of postoperative asymmetry between the vocal cords. Thus, I now place the marking suture in the mid-portion of the vocal cords in everyone before removing the anterior vocal cords. It acts as a marker for where I intend to place a cut as well as the suture to maintain symmetry. This also defines for me the area of the vocal ligament. When the vocal cord is cut, it not only contracts posteriorly toward the vocal ligament, it flattens out against the lateral aspect of the thyroid cartilage. It can be difficult to locate the vertical level of the vocal ligament after releasing it.

Suturing the new anterior commissure: In early cases I placed an additional suture into each vocal cord in order to tension the thyroarytenoid muscle separately from the new anterior commissure. Before placing the opposing horizontal mattress sutures which create the new anterior commissure, I drilled two additional holes into the thyroid cartilage at the level of the anterior

commissure. I passed a nylon suture through the cut anterior end of the thyroarytenoid muscle. This was brought out of the glottis and passed into the thyroid cartilage from externally to internally, then back out of the thyroid cartilage via the other hole. As this suture was tightened, the central portion of the thyroarytenoid muscle was pulled up to the cut edge of the inner thyroid lamina. If there was too much thyroarytenoid muscle, such that it could be pulled out along the cut edge of the thyroid cartilage, then the suture was cut and more thyroarytenoid muscle resected. This type of suturing made further work internally more difficult since if the thyroid alae were pulled laterally for exposure after suturing the thyroarytenoid muscle, this suture would tear out of the muscle. I remain unconvinced that it added any pitch gain and it added time and technical difficulty to the procedure.

Voice rest: With the initial patients I did not suggest any voice rest. Many patients when they initially speak have a deeper comfortable speaking pitch, presumably because of the easily visualized swelling of the transected vocal cords. Some patients seem to have tight enough vocal cords with minimal swelling and have a higher pitch even the first week after surgery. One patient, with an initial great result, began singing one week after surgery. She felt a pop and noted that her comfortable speaking pitch dropped. Since that time, I have requested two weeks of voice rest and a number of patients have voluntarily undergone three weeks of voice rest if their occupation allowed.

Subcutaneous emphysema: This might result from lack of an airtight closure or from an aggressive cough. Some patients will feel a need to cough from a tickle, or to clear secretions, or to clear a blood clot from the internal incision or even from a sensory illusion, the result of the swelling that places the anterior cords in apposition to each other. Isolated or infrequent coughing does not necessarily cause a problem. However, heavy or ongoing coughing may lead to subcutaneous emphysema. I have managed this with expectant waiting or on an occasion with placement of a drain. If air is leaking from internally, there also seems to be a higher associated rate of infection.

Postoperative airway compromise: All of the iatrogenic airway compromise I have seen has been from supraglottic edema and principally from edema on the posterior aspect of the arytenoids. I believe there are two probable etiologies for this edema. One is infectious. The other seems to be from extension of the resection along the superior edge of the thyroid cartilage toward the superior thyroid cornu. After realizing that some supraglottic edema is a result of surgical dissection posteriorly along the superior border of the thyroid cartilage, I began to remove only the anterior two thirds of the upper thyroid ala. I feel that I can still elevate and suspend the larynx from the hyoid bone without removing thyroid cartilage all the way to the superior cornu.

Edema seems to peak on postoperative day number three. Infections seem to be identifiable by day three or else an infection tends not to occur. I have not seen any airway compromise from edema at the level of the glottis either early or late.

After one infection, where I inadequately drained a subcutaneous collection of purulence, the following day I placed a temporary tracheostomy and drained a deeper collection of purulence beneath the strap muscles. For a number of patients after this I then placed a drain at the time of skin closure. This drain seemed to make no positive difference in the rate of infection and perhaps increased the rate of infection, so I have not been placing drains since. After switching preoperative antibiotics to a combination of clindamycin and a third generation cefalosporin, combined with 7 days of postoperative cefuroxime or levofloxacin, I have encountered no severe infections.

I very aggressively try to ensure an airtight closure of the incision into the larynx. My present management approach is that if on endoscopic examination on postoperative day number two or number three there is any suggestion of infection including either supraglottic edema, supraglottic erythema, increasing pain, subcutaneous fullness or subcutaneous fluid collection then I will treat aggressively for presumed infection. This includes needle aspiration of any potential subcutaneous fluid collection, culture and I start oral antibiotics.

In all cases of infection persisting beyond ten days, I have ultimately returned the patient to surgery and removed the hardware or suture that was associated with the ongoing infection. The plate and GoreTex sutures, if removed after one month, are no longer needed and the anterior commissure remains well attached.

One patient felt moderately short of breath, yet had only typical mild supraglottic swelling, not enough to cause symptoms of an airway restriction. After a strong cough expectorated a clot, which must have been present in one of the bronchi, her sense of dyspnea resolved.

Asymmetry: I noticed varying degrees of asymmetry of the vocal cords on stroboscopy of patients from my very first procedure. While sometimes asymptomatic, there can be some pitch where asymmetric cords cause dysphonia, specifically diplophonia. If this is at the comfortable speaking pitch, the patient may learn to elevate or lower the pitch slightly to avoid the rough spot. Initially, when severe enough, I tried to correct the asymmetric tension with a revision surgery. 15 of the first 69 patients received a revision surgery. This correction of asymmetry was difficult to accomplish with scar tissue from the initial surgery being present and it was difficult to judge the exact amount to remove.

On one patient with particularly severe dysphonia after an infection, I utilized an office laser to create a burn on the superior surface of the looser vocal cord, which tightened, correcting the dysphonia. It also raised the pitch slightly.

Since then, I have used the pulsed dye laser, but more recently have preferred a KTP laser for vocal cord tightening. Using a flexible laser fiber passed through a flexible laryngoscope has proven to be a very cost effective means of correcting surgical asymmetries.

The laser can also be applied bilaterally to raise the pitch. If I tighten both sides, I frequently can obtain an additional semi-tone of pitch elevation. This office laser procedure may be repeated after two to three months. I don't know the limit of how much pitch elevation may be obtained with additional treatment(s).

Elevation of larynx: On the first patient which I tried a thyrohyoid elevation, I was able to elevate the larynx just by passing sutures through the upper thyroid cartilage and the hyoid bone, but in my second patient and in many patients since, the upper edge of the thyroid cartilage abuts the hyoid bone precluding additional elevation. I presently consistently remove one vertical centimeter of upper thyroid cartilage, which gives additional room to raise the larynx in the neck. It also gives the appearance during surgery of a more typical female sized thyroid cartilage.

Elevation of the larynx changes only one of several anatomical features that contribute to resonant frequency. Other anatomical differences that affect resonance (ie. the sinuses) cannot easily be surgically manipulated to produce a more feminine resonance. However, one anatomic area that might also be surgically manipulated is the diameter of the pharynx. There may be a way to plicate the pharyngeal walls and narrow the circumferential dimension of the pharynx, improving reso-

nance of higher pitches. Or perhaps one might devise a subcutaneous augmentation to narrow the pharyngeal diameter in a way analogous to an obese person's narrowed pharynx.

Most patients note a loss of volume, both in everyday speech and for a yell. In most cases she cannot replicate the volume of her previous voice. Subjectively, some patients are pleased with the softness of their new voice or may consider it a reasonable trade-off.

Numerous patients did not initially perceive a change in their voice after surgery. I suspect we are used to hearing our voices via internal bone conduction. Additionally FemLar does not change the accent nor character of the voice after surgery. While documentation is important in many respects (for the surgeon to learn what works, legal documentation, etc.), it is invaluable to the patient as well to hear the difference in pitch on a recording. After hearing the pre and post-operative recordings, many patients gain confidence in her new voice.

Conclusion

Feminization laryngoplasty, including a thyrohyoid elevation component and possibly a later postoperative laser tuning, is a surgical technique designed for individuals wishing to transition from a male to female voice by increasing the fundamental and resonant frequencies of her voice.

Online media References

Voice samples are available at http://www.voicedoctor.net/Surgery/Pitch/Feminization-Laryngoplasty

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