Pitch Elevation in Trangendered Patients: Anterior Glottic Web Formation Assisted by Temporary Injection Augmentation

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Summary: Pitch elevation surgery is most often indicated to assist male-to-female transgendered individuals seeking a more feminine voice quality. Behavioral therapy is primary management but if the desired voice quality is not achieved, surgery is offered. Procedures described that raise vocal pitch alter one or more of the main parameters known to physiologically control pitch; vocal fold tension, length, and mass.

Objective. Web formation with injection augmentation significantly raises vocal pitch in male-to-female transgendered individuals.

Study Design. Retrospective cohort study.

This report describes the voice results after anterior web formation with injection augmentation to reduce vocal fold length in a series of 10 transgendered patients.

Methods. Retrospective review of male-to-female transgendered patients referred to St. Michaels Hospital Voice Clinic, Toronto, Canada for pitch elevation was carried out including demographic data, preoperative and postoperative acoustic data and videostroboscopic evaluation.

Results. Comparison between preoperative to postoperative acoustic measures demonstrated a mean increase in fundamental frequency of 110 Hz after web formation. Perturbation measures and pitch range were unchanged from before surgery to after surgery.

Conclusion. This novel modification for endoscopic anterior web formation has been shown to be a successful procedure for permanent elevation of pitch with little or no morbidity.

Key Words: Pitch elevation–Transsexual voice–Endoscopic laryngeal surgery.

INTRODUCTION

Elevating vocal pitch is an uncommon indication for surgery and has been done primarily for male-to-female transgendered individuals who desire their voice to be perceived as female, consistent with their psychological gender identity. Gender dysphoria or transgendered[1–4] is a state in which an individual is convinced that one's personal psychological gender is inconsistent with their phenotype or physical gender. The distress associated with this condition may cause an individual to seek medical or psychological intervention. Multidisciplinary care is the current practice standard[3] for these individuals who often require medical, surgical, and psychological treatment from a variety of specialists. Most of the male-to-female transgendered individuals receive hormone therapy (estrogen) however it has been shown to have little effect or no effect on voice quality.[4,5] A voice quality perceived as male conflicts with the psychological female identity in these individuals. Not infrequently, transgendered individuals will seek treatment from a laryngologist and/or a speech language pathologist to achieve agreement between their perceived gender (based on their voice) and their psychological identity.

Perceptual research on gender identification based on voice and speech characteristics have found that the primary cue in gender identification is "pitch".[5–9] Although there is overlap in the standard deviation of male and female average speaking fundamental frequency (SFF) range, Spencer[7] and Wolfe[10] found that an SFF of above 160 Hz were more likely to be identified as female and below 150 Hz subjects were more reliably identified as male speakers. Vowel formant frequencies (F2) have also been found to be higher in women[5,6,8,11] and in transgendered individuals identified as female.[7,12] Gelfer et al[6] also reported in their study of 15 male-to-female transgendered individuals that an SFF of 160 Hz was insufficient for female gender perception and a mean SFF of 187 Hz was observed in the transgendered subjects who were identified as female.

Resonance characteristics such as formant frequencies are not only higher in women[9,13] (20%) but are also a salient gender cue in connected speech particularly if the SFF of the individual is in the unclear zone between 145 and 165 Hz.[12,14] An individual can acquire the skills to modify their vocal resonance by altering vocal tract shape with intensive speech therapy. Therapy also addresses nonsegmental aspects of speech such as prosody, resonance focus and loudness[7,13,15–18] to achieve a feminine voice quality. The therapy is resource and time intensive and it has not been uniformly successful with considerable individual variation.[7,8,12,13,15–19] Also, patients report that a lower "male" voice emerges during nonspeech voice tasks like laughing/coughing and long-term maintenance of the "feminine" voice has been problematic.[12,15]

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At our tertiary voice center, transgendered individuals seeking a more female voice quality are offered speech therapy and surgery is reserved for unsatisfactory outcome or if an individual does not have access to these specialized services. This approach is consistent with the recently published Good Practice Guideline[3] for Gender Dysphoria published by the Royal College of Psychiatrists (2013).

Surgical options

The main parameters for physiological manipulation of pitch are surface tension (cover stiffness) and vocal fold mass and length[20] following the simplistic model of a vibrating string. One of the first procedures described by Isshiki[21] for pitch elevation was cricothyroid approximation (CTA) which increases tension by tilting the larynx inferiorly and suturing/plating the lower border of the thyroid ala to the upper border of the cricoid, reproducing the activation of the cricothyroid muscles. A series of 21 patients reported a median pitch elevation of >55 Hz after CTA[22] and other reports show similar results.[23,24] Although easy to perform and the procedure can be done under local anesthetic, the disadvantages include enhancing the prominence of the thyroid notch, potential reduced pitch range,[13,24] and initial pitch rise was not retained in some patients long term.[23,24]

Anterior glottic web formation has been performed by both external and endoscopic approaches to shorten the vibrating length of the vocal folds to raise pitch. The normal male adult vocal fold is roughly 1.5 times longer than a female and its cross sectional mass is also larger. Fundamental frequency varies inversely with vocal fold length[25] if all other parameters are constant and on this basis, reducing vocal fold length by one third should raise the F_0 into a female range. This is not the case in transgendered individuals and shortening the vocal fold length by one third may be insufficient to accomplish a "female" voice given the phenotypic male vocal tract and vocal fold mass.

External approaches have included laryngofissure and suturing of the anterior vocal folds[26,27] and more recently, "feminization laryngoplasty" which consists of excision of the anterior thyroid ala and vocal folds with reconstruction.[28,29] A large series of 76 patients who underwent feminization laryngoplasty reported an increase in SFF of more than 50 Hz (6 semitones ST). However, revision surgery was required because of unequal tension or patient dissatisfaction in 27%.

Other endoscopic approaches to reduce muscle mass using muscle excision or laser[30–32] have had less promising results. Technical issues in endoscopic procedures to shorten the vocal folds by web formation[26,33] have been hampered by suture dehiscence, anterior commissure blunting, and insufficient reduction in vocal fold web length.

The ideal surgical procedure for raising vocal pitch should be reliable with little or no morbidity and permit the individual to use a normal intent and effort when speaking with a F_0 higher than 165 Hz to be perceived as female.

This report is a case series of voice results in male-to-female transgendered individuals after web formation surgery. The technique is based on a previously described novel technique of anterior glottic web formation.[34] However, the technique has been modified and simplified by altering the augmentation material from Gelfoam powder (Pfizer, Kalamazoo, MI) to Radiesse Voice Gel (Merz Pharma, Frankfurt, Germany). This report demonstrates that anterior web formation with injection augmentation is an effective, endoscopic method of dramatically raising pitch with no statistical difference in pitch range and perturbation measures after web surgery.

METHODS

A retrospective chart review of male-to-female transgendered individuals referred for pitch elevation to the Voice Clinic at St. Michaels Hospital (between January 1, 2000 and June 30, 2012) a tertiary referral laryngology center was carried out. All subjects were offered primary behavioral therapy. If patients continued to express dissatisfaction with their voice quality after therapy, then endoscopic web formation was offered as surgical treatment. One patient could not attend therapy sessions because of travel distance. A detailed questionnaire was collected including demographic data, medical history, and past treatment for their voice.

All subjects met the following inclusion criteria:

1. Age between 22 and 65 years
2. Currently in a formal program for gender dysphoria or attending a specialty clinic
3. Female hormone replacement therapy and living full time as a woman for more than 3 years
4. No other laryngeal pathology other than prior pitch elevation procedures or laryngeal shave
5. No history of speech, language, or hearing problem
6. Nonsmoker

Subjects were excluded if they had other laryngeal pathology, were medically unfit for surgery, or did not consent.

Videostroboscopic examination by the principal investigator and voice recording for acoustic data were carried out by a speech language pathologist in a sound treated room.

Postoperative evaluation was done at 6 months with annual follow-up when possible.

Data collection preoperatively and postoperatively included the following:

1. Videostroboscopy
2. Acoustic Recording including
   a. Vowel tokens (three trials)
   b. Pitch Range (best of three trials)
   c. Reading task (Rainbow passage)

Videostroboscopic examination

Videostroboscopy was carried out to screen for other laryngeal pathology and as standard of practice for voice evaluation. Whenever possible, rigid laryngoscopy was done with a 70° Storz (Karl Storz, Tuttlingen, Germany) scope with a c-clamp triple chip CCD Toshiba camera (Toshiba Corporation, Kawasaki, Japan). Files were stored on the KayPENTAX 9400 videostroboscopic computer system (KayPENTAX, Lincoln Park, NJ). If poorly tolerated, a flexible endoscope

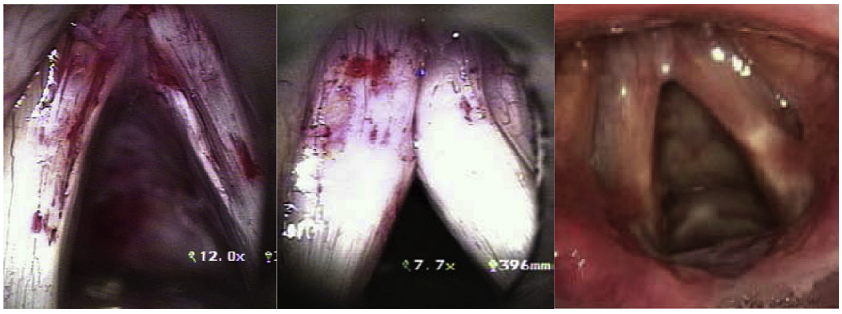

FIGURE 1. The intraoperative photo on the left shows the de epithelialised medial vocal fold border edges. The centre photo shows post Radiesse injection to approximate the medial edges. The right photo is from a post operative indirect laryngoscopy during maximum abduction with anterior web.

was done. The standard stroboscopic protocol was performed including habitual vowel /i/, pitch glide, and respiratory tasks.

Acoustic data collection

All audio recordings were carried out in the St. Michaels Hospital Voice laboratory in a sound treated audiometric booth. Audio samples were digitally recorded using the Computerized Speech Lab 4500 with the *Multidimensional Voice Program*, Version 3.3.0 (KayPENTAX, Lincoln Park, NJ) Each patient had three vowel tokens /a/ recorded at habitual pitch and loudness. Acoustic analysis which was carried out on a 1000 ms segment after the first 100 msec was trimmed to remove voice onset. Pertubation measures (percent jitter [JITT] and shimmer [SHIM]) from each trimmed vowel token were noted. An individual mean for each acoustic parameter was calculated then grouped for comparison from before to after surgery.

Pitch range including modal and falsetto phonation (fundamental frequency) was recorded using the *Real-Time Pitch program*, Version 3.3.0 (KayPENTAX, Lincoln Park, NJ). Three trials were recorded and the best range noted in both Hertz and semitones (ST).

The subjects read the Rainbow passage, a standardized text, at a comfortable pitch and loudness.

At 6 months postsurgery, the postoperative acoustic data were collected then grouped and compared with preoperative data. Statistical analyses were conducted using *SPSS 21* (Statistical Product and Service Solutions; IBM, Armonk, NY) with before and after surgery measures compared using paired-sample t test with significance level set at 5% ($P = 0.05$).

Procedure: anterior web formation and Radiesse injection augmentation

Direct suspension microlaryngoscopy was carried out under general anesthesia after placement of a small endotracheal tube (number 6). The entire membrane vocal fold length is inspected and the anterior 40–50% of free edge epithelium was excised using curved microscissors.

To promote the formation of an acutely angled "new" anterior commissure, the epithelium is incised as precisely and symmetrical as possible. Microscissors were used to undermine the mucosa which was elevated anteriorly and across the anterior commissure. The ellipse of mucosa was removed symmetrically to deepithelialize the vertical edge of the vocal folds tapering to an acute angle at the posterior end of the excised tissue (Figure 1). This was done with as precise symmetry as possible. Radiesse Voice Gel was then injected using a 24 gauge endolaryngeal needle into the thyroarytenoid muscles to medialize the anterior vocal fold such that the deepithialized edges were in direct contact with the opposite vocal fold. Each fold typically requires 1–2 cc of Radiesse. Small amounts can be injected into the lamina propria to precisely oppose the free edges in the vertical plane. The injection augmentation is crucial to

TABLE 1.
Acoustic Data Presurgery and Postsurgery (n = 10 patients)

Acoustic Data	Minimum	Maximum	Mean	Standard Deviation (SD)
F_0 Pre Hz	96.00	155.00	127.78	21.67
F_0 Post Hz	169.00	360.00	238.00	59.78
JITT Pre %	0.50	5.00	1.84	1.53
JITT Post %	0.37	3.20	1.34	0.91
SHIM Pre %	1.80	6.20	3.38	1.47
SHIM Post %	2.10	3.50	2.89	0.46
Range Pre (ST)	9.00	37.00	24.33	9.01
Range Post (ST)	12.00	38.00	22.00	8.23

Abbreviations: F_0, fundamental frequency, mean from three trial vowel samples; JITT, percent cycle to cycle variation in fundamental frequency; SHIM, percent cycle to cycle variation in amplitude; Range, pitch range in semitones including model and falsetto register.

TABLE 2.
Statistical Analysis: Comparison of Acoustic Data from Presurgery to Postsurgery (n = 10 patients)

Paired-Samples *t* Test	Mean	SD Standard Deviation	Significant (Two Tailed)
F_0 Post-Pre (Hz)	**+110.22**	57.14	**<0.001**
JITT Post-Pre (%)	−0.50	1.95	0.460
SHIM Post-Pre (%)	−0.49	1.63	0.395
Range Post-Pre (ST)	−2.33	5.56	0.244

Notes: Fundamental frequency (F_0) was significantly elevated post web formation surgery (bold). Perturbation measures and pitch range showed no statistically significant change from pre- to postsurgery.

approximation of the deepithilialized edges without suturing. Previously, 5 g of Gelfoam powder (Pfizer, MI no longer available in Canada) reconstituted as a paste with normal saline was used to medialized the folds via a teflon injector.

Patients were placed on total voice rest for 3 days and minimum voice use for the following 2 weeks until assessed in the voice clinic.

RESULTS

There were 10 male-to-female transsexual patients included in this report with a mean age of 42 years with a range from 25 to 58 years. Hormone replacement therapy in some form of estrogen was being taken by all patients for between four and 14 years, with a mean of 7.2 years. Two patients had previous endolaryngeal laser procedures to attempt web creation which were unsuccessful and induced a significant dysphonia with elevated perturbation measures. All other patients had normal preoperative perturbation measures based on the habitual pitch and loudness vowel token samples. Preoperative F_0 mean was 127.8 Hz (B2) with a range of 96–155 Hz preoperatively which is well within the normal male voice range.

Table 1 summarizes preoperative and postoperative acoustic data including F_0, JITT, SHIM, and pitch range.

Web formation was documented 2 weeks postoperatively by indirect laryngoscopy. Considerable laryngitis with marked increased vascularity and erythema is also typical on the first postoperative examination. The voice quality at this time is quite strained and rough because of the inflammation and continued presence of the augmentation material. At 6 weeks postoperatively, most patients felt their voice had improved considerably with little dysphonia remaining. The typical length of the anterior web was judged by the author to be between 40 and 50% of the original vibrating vocal fold length.

Surgical complications were minor, including one patient with altered sensation in the tongue transiently after direct laryngoscopy and all patients reported up to 6 weeks of moderate to severe dysphonia associated with postsurgical laryngitis. Four of the ten patients reported that their voice had reduced loudness for several months after surgery but spontaneously improved by 6 months. One patient developed a 2 mm edge granuloma in the center of the web which spontaneously resolved.

Follow-up period in the group was a mean of 22 months (range, 6–60 months) after web formation surgery.

A paired-samples *t* test was carried out on the grouped preoperative and postoperative data and are summarized in Table 2. The group mean (Figure 2) F_0 preoperatively and postoperatively was 127 (range 96–155) Hz and 238 (range 169–360) Hz. This was a statistically significant increase of 110 Hz ($P < 0.001$). The fundamental frequency increase effect did not change over the follow-up period ranging from 6 months to 24 months (mean 10 months).

Two patients had abnormal perturbation measures because of postsurgical scarring from prior laser procedures in attempts to raise pitch that improved after web formation. All other subjects had normal JITT and SHIM preoperatively and postoperatively with no significant change ($P = 0.460$ and $P = 0.395$, respectively) from before to after surgery (Table 1).

Comparison of pitch range (Figure 3) in ST was not significantly different with a group mean of 24 ST before and 22 ST after surgery ($P = 0.900$).

DISCUSSION

This report describes anterior glottic web formation assisted by injection augmentation to raise pitch which has been successful in dramatically raising the fundamental frequency. The procedure is easy to perform but requires attention to precise mucosal excision and sufficient augmentation to medialize the anterior vocal fold edges for success. A web of 40–50% of the vibratory vocal fold results in a dramatic increase in fundamental frequency in male-to-female transgendered individuals.

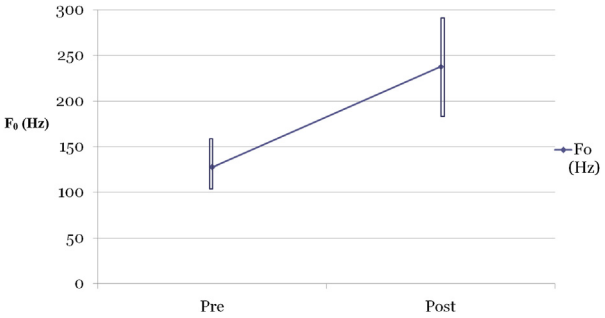

FIGURE 2. Habitual fundamental frequency before to after surgery. Rectangles show confidence interval of before and after surgery fundamental frequency in Hertz (Hz). Paired-samples *t* test of the group mean F_0 difference showed an increase of 110 Hz which is statistically significant ($P < 0.001$).

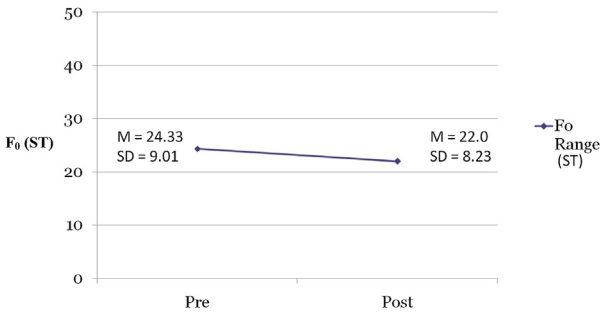

FIGURE 3. Pitch range before and after web formation. Paired-samples *t* test comparing preoperative to postoperative pitch range showed a mean difference of −2.33 ST which did not reach significance ($P = 0.244$).

In addition, the technique has been modified and simplified by using Radiesse Voice Gel rather than Gelfoam powder reconstituted as a paste. The paste was awkward to load into the teflon injector and required a large bore needle to be injected (at least 19 gauge). The larger needle also caused more trauma to the vocal folds and at times the material could extrude back out through the puncture site. Radiesse Voice Gel can be injected with a 24 gauge needle (accompanies material prepackaged) and permits a more accurate depth and vocal fold site injection to approximate the free edges as precisely as possible.

Advantages of this technique include minimal invasive nature of an endoscopic approach with no statistically significant change in pitch range or perturbation measures after surgery. This technique has also been used successfully in a small group of women (not included in this report, anecdotal data from the same institution and author) who have androphonia either due to polycystic ovarian disorder or androgenic steroid use and in one patient with Klinefelter syndrome. Further areas of study include a perceptual study to evaluate the gender identification based on voice quality after web formation, and long-term follow-up for this technique.

CONCLUSIONS

Although pitch elevation is not a common endolaryngeal procedure, the vibrating length of the vocal folds can be reliably shortened by anterior glottis web formation using this novel technique. The elevation of vocal pitch after surgery is dramatic but without the negative adverse effects of altering pitch range or perturbation measures in this series of transgendered individuals. The technique is relatively easy to perform with minimum complications.

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