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Endoscopic and Stroboscopic Presentation of the Larynx in Male-to-Female Transsexual Persons

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Abstract

Background. Male-to-female transsexual (MFT) persons often attempt to produce a female-sounding voice as part of the transition process. Endoscopic and stroboscopic data about how they accomplish this with an anatomically male larynx are lacking.

Objectives. To describe vocal fold activity in MFT persons producing their feminine voice and identify signs of vocal misuse or hyperfunction in MFT speakers, if any.

Study Design. Prospective, nonrandomized, descriptive study of a convenience sample of MFT persons.

Methods. All MFT persons had endoscopic and stroboscopic procedures completed. Images were rated on a range of parameters by two experienced voice therapists to derive the descriptions. MFT participant self-report of voice use/ symptoms and listener identifications of speaker gender from a perceptual task were also obtained.

Results. Incomplete glottal closure was common with a posterior glottal gap predominating. Phase closure ratios also were skewed toward more "open" time for nearly half of the group. Supraglottic constriction was seen to varying degrees in all, and voice complaints were reported by 67% of the group.

Conclusions. MFT speakers who reported a "passing" feminine voice had glottal gap configurations more similar to anatomic females than males and tended toward more open phase closure ratios, perhaps consistent with breathy or soft voice production. Indications of vocal hyperfunction were present for all participants either by self-report or on the laryngeal examination.

Keywords: Transsexual, Voice, Larynx, Stroboscopy, Male-to-Female

Introduction

Transsexualism is a condition in which a person believes that his or her psychological gender is incongruent with his or her anatomic gender.[1] In an attempt to correct this incongruence, many transsexual persons make the decision to live their lives in the opposite gender role. The World Professional Association of Transgender Health has outlined a series of standard steps that guide medical professionals who assist in the gender transition process.[2] These steps include time with a mental health professional, hormone replacement therapy, ''real-world test,'' and sexual reassignment surgery, if the individual so chooses. Additionally, some transsexual individuals choose to alter their voice to more closely resemble that of their preferred gender. Although female-to-male transsexual individuals can often achieve this voice change through the administration of testosterone, [3] hormone replacement therapy with male-to-female transsexual (MFT) individuals does not make the voice sound more feminine.[4]

Achieving a feminine voice is typically an important component to the overall gender transition process of MFT individuals. Changing the physical appearance of the body and face is possible through hormone therapy, plastic surgery, cosmetics, wardrobe, hairstyle, body hair removal, and sexual reassignment surgery. However, if the voice and physical appearance are incongruent, it may prevent an MFT person from being viewed as a member of her preferred gender in society.[5,6]

Feminizing the voice and communication of MFT individuals can be a lengthy and complex process. Individual situations and needs differ, and the literature indicates that successful voice feminization for MFT individuals typically involves manipulating and changing several rather than a single voice or communication feature. A number of parameters have been suggested as potential therapeutic targets, including habitual pitch,[7–11] loudness,[12] vocal quality,[13] resonance,[6,9] and intonation patterns,[14] in addition to linguistic and paralinguistic features.[1,15,16] Not all the suggested therapeutic targets involve the larynx but many of them do. Pitch manipulation for MFT individuals has been the most investigated parameter over the years, perhaps because it is known to be a salient feature of voice that helps a listener determine a speaker's gender.[17–19] However, pitch alterations may not be necessary in some cases, and may not be sufficient on their own in most others, to achieve an acceptable feminine voice in MFT individuals.

MFT individuals attempting to feminize the voice may be working within anatomic and physiological constraints imposed by their larynx, which increase the challenge of modifying phonatory-related behaviors. By definition, an MFT person is anatomically male; the larynx in males is typically larger, and the vocal folds are longer and more massive.[20,21] Söderpalm et al[11] reported endoscopic information regarding the larynx in MFT persons followed up for communication intervention. They indicated no structural

differences of MFT individuals compared with nontranssexual males. Larger and more massive vocal folds are suited for production of a lower mean fundamental frequency, and perhaps greater intensity, both of which have been reported for males.[17–19] In terms of laryngeal and vocal fold activity, more complete glottal closure is expected during phonation for males, whereas a higher percentage of females present with a posterior glottal gap,[22,23] which likely contributes to listeners' perceptions that females are breathier than males.[24–26]

Despite the challenge of producing a female-sounding voice with a larynx that is perhaps better suited for producing a masculine voice, many MFT individuals are quite successful at altering their voice. Investigators and clinicians interested in voice feminization for MFT persons frequently make inferences about how an individual alters laryngeal function to produce a feminine voice. However, direct investigation of laryngeal activity in MFT persons who have not had laryngeal surgery is very limited with perceptual and acoustic investigations predominating.

Visual information about laryngeal activity during voicing in MFT speakers is important for two reasons. First, understanding the type of laryngeal and vocal fold behaviors that are associated with successful voice feminization can allow better definition of therapeutic targets at the laryngeal level. That is, clinicians might have a better idea of the various ways in which MFT individuals might adjust laryngeal behavior to achieve the perceptual goal of a feminine voice. Endoscopy and stroboscopy could be incorporated into the therapy approach with specific visual configurations or movements as the target. Second, there has been ongoing concern in the literature about the possibility that some MFT persons may engage in harmful laryngeal behavior when using their feminine voice. Söderpalm et al[11] noted supraglottal constriction during phonation in over half of their MFT participants; the authors speculated that the supraglottal constriction was associated with vocal fatigue. Mézáros et al.[4] calculated the Friedrich dysphonia index for five MFT participants, three of whom were receiving voice treatment and two who were not. The dysphonia index scores from the three MFT participants who received voice treatment reflected a reduction in hyperfunctional voice production, whereas the index for the two untreated individuals indicated persistent hyperfunction at a level that was considered pathologic. Oates and Dacakis[1] and Söderpalm et al,[11] among others, have advocated voice therapy for MFT clients who are seeking to feminize their voices to prevent use of potentially abusive vocal behaviors. Despite the expressed concern about increased vocal hyperfunction in MFT persons, only a few descriptions of laryngeal behavior from visual observations are in the extant literature.

The purposes of this study were to describe laryngeal and vocal fold configurations and movements from endoscopic and stroboscopic examinations of MFT persons using their feminine voice and identify any potentially harmful vocally abusive behaviors during feminine voice production and describe tissue changes within the larynx, if any.

Methods

Participants

Nine MFT persons (mean age: 50 years; range: 33–71 years) volunteered for this study. All were on hormone therapy. Table 1 presents additional information about the participants. Inclusion criteria were self-identification as an MFT person, normal male voice before transitioning (self-report), living in the female role at least 75% of the time for the past 6 months, and ''passing'' female voice per self-report (i.e., the MFT person reported that her voice was routinely perceived by others as a woman's voice). Exclusion criteria were surgery to the vocal tract, which would alter speech and voice, and medical conditions that are routinely associated with speech or voice abnormalities. This study was approved by the Human Subject Committee at the University of Kansas Medical Center, and all participants signed a written consent before participation.

A group of age-matched adults, one male and one female within ±2 years of each MFT participant, were also gathered to serve as controls during a perceptual listening experiment conducted to assess the extent to which listeners identified the MFT participants as male or female. These non-MFT participants also self-reported normal voice, currently and in the

Table 1. Biographical Data of MFT Participants

Participant	Age (y)	Years Spent in Female Role 100% of the Time	Sexual Reassignment Surgery	Other Surgeries Involving Head/Neck
1	38	1	No	None
2	71	8	No	Septoplasty
3	33	6	Yes	Intubation
4	49	4	Yes	Tracheal shave, upper lip reduction
5	51	8	Yes	None
6	51	2	Yes	None
7	61	3	No	None
8	54	12	Yes	None
9	43	2	No	None
Summary	Mean = 50.1	Mean = 5.2	Yes = 5 (56%)	
	SD = 10.9	SD = 3.4	No = 4 (44%)	

Abbreviation: SD, standard deviation.

past, and no surgery or medical conditions that would impact voice or speech.

Instrumentation

A Pentax VNL-1170K flexible nasoendoscope (PENTAX Imaging Co., Golden, CO) coupled to a Pentax EPK-700 digital camera (PENTAX Imaging Co.) and a KayPENTAX Digital Strobe (v. 6.2.1; KayPENTAX, Lincoln Park, NJ) was used to record, display, and archive the laryngeal examination. A throat microphone was positioned on the neck to trigger the stroboscopic light. In addition to the acoustic recording done with the KayPENTAX system using a lapel microphone, an AKG C410 headset microphone (AKG Acoustics, Vienna, Austria) was positioned on the participants head approximately 10 cm away from the corner of the mouth. The headset microphone was coupled to a Marantz PMD300 portable CD recorder (Marantz America, Inc., Mahwah, NJ) to obtain a simultaneous audio recording that was used to determine mean fundamental frequency (F_0) for each speaker. This recording was also used for the perceptual listening experiment. The perceptual listening experiment was constructed using *Alvin2* software (beta version; James M. Hillenbrand, Western Michigan University, Kalamazoo, MI; shareware available at http://homepages.wmich.edu/~hillenbr) and is described in more detail below.

Procedures

Data collection took place in one session lasting approximately 30–60 minutes. After completing a history questionnaire, participants were seated in an examination chair in the stroboscopy suite. A state-licensed speech-language pathologist (SLP) with 4 years of exclusive work in the area of voice disorders and laryngeal endoscopy and stroboscopy performed the examinations. For the flexible scoping procedure, an aerosolized vasoconstrictor was administered into the most patent nasal passage; a small amount of aerosolized lidocaine was also administered. The scope was positioned to allow a full view of the larynx, and recordings were made of the following: (1) quiet breathing (10 seconds, continuous light), (2) sustained /i/ at a comfortable pitch and loudness (5–10 seconds × three trials, stroboscopic light), (3) ascending and descending pitch glides on /i/ (~5 seconds × three trials for each; stroboscopic light source), and (4) reading a portion of the Rainbow Passage[27] (× one trial, continuous light).

Measurement

Endoscopic and stroboscopic image analysis. Two state-licensed SLPs with a minimum of 4 years of clinical experience in the area of clinical voice disorders including evaluation of endoscopic and stroboscopic recordings provided independent ratings of the laryngeal examinations using a modified Stroboscopy Evaluation Rating Form (SERF).[28] Parameters rated included symmetry of laryngeal structures at rest (vocal folds, ventricular folds, aryepiglottic folds, and epiglottis), amplitude of excursion of vocal fold edge (degree and symmetry), mucosal wave excursion (degree and symmetry), supraglottic activity (degree and symmetry), vocal fold edge smoothness and straightness (irregularities and symmetry), vertical level of the vocal folds (symmetry), phase closure, phase symmetry, regularity of vocal fold vibration, glottal closure configuration, tissue color, presence/absence of vocal fold edema and vascularity, mucus in the larynx (excess, thickness, and location), laryngeal height adjustments, and pharyngeal tension. Raters were allowed to watch each examination as many times as they needed to make their ratings. The raters then reviewed their ratings and the video together and arrived at a consensus rating for each parameter. The SLP raters were not involved in the scoping procedures and had not met any of the MFT participants. They were not told that the focus of the study was on MFT individuals.

Perceptual ratings of voice. Although the participants self-reported that they had a ''passing'' feminine voice, listener perceptions of the voice were of interest to confirm or refute this report and potentially help in the interpretation of the imaging data. Ten young adults (23–28 years; nine females and one male) with little to no exposure to MFT persons served as listeners. There were two blocks of audio stimuli in the listening experiment: 2-second clips of sustained /i/ and the second sentence of the Rainbow Passage. Sustained vowel and the second sentence of the Rainbow Passage were also extracted from audio recordings of age-matched male and female controls. *Alvin2* software was used to construct a listening experiment wherein samples were fully randomized across MFT participants and controls within blocks (sustained /i/ and sentence reading). All the recordings from the MFT participants and ~25% of the control recordings were included twice in the experiment for estimation of listener agreement.

Listeners completed the experiment individually in a quiet laboratory room using *Alvin2* software, a laptop computer, and high-quality computer speakers. The software randomly selected a voice clip, played it over the computer speaker when the listener clicked a button on screen, and provided an onscreen environment for the listener to identify the gender of the speaker as either male or female. Listeners were not told at any time that some of the voices they were hearing were MFT persons. The order of completing the two listening blocks (sustained vowel productions and sentence reading) was counterbalanced across the set of 10 listeners.

Fundamental frequency analysis. The audio stimuli used for the perceptual ratings (2-second clip of the modal /i/ and second sentence of the Rainbow Passage) were also analyzed using *PRAAT* (v.5.1.02; http://www.fon.hum.uva.nl/praat/ developed by Boersma and Weenick, University of Amsterdam, Amsterdam, The Netherlands) to determine the mean F_0. The primary focus of this study was on the visual presentation of the larynx. However, given that F_0 is a salient feature for identification of a speaker's gender, it was of interest to track the F_0 of the MFT participants.

Analysis

Endoscopic and stroboscopic data. The primary data analysis was descriptive in nature with the intention of informing about the laryngeal presentation of MFT persons producing their feminine voice. Depending on whether a parameter was judged categorically or scaled in some fashion, frequency

distributions and measures of central tendency were computed. The consensus ratings (rather than the two independent SLP ratings of a given sample) were used in this descriptive analysis.

To evaluate whether one SLP dominated in the consensus decision-making process, the independent ratings from each of the two raters were evaluated relative to the final consensus decision. There were 144 consensus decisions (16 parameters to rate × nine participants). A total of 95 of these were exact agreements between the two raters (66%). Twenty-five (17%) of the remaining consensus decisions were the same as the independent rating from SLP rater 1, 21 (15%) were the same as SLP rater 2, and three (2%) were a compromise that was neither the independent rating from SLP rater 1 nor SLP rater 2. This agreement data suggested that the two SLPs agreed exactly on most decisions, and when they disagreed, both contributed equally in the consensus process.

Listener perception data. The analysis was intended to determine the extent to which listeners accurately identified the intended gender of the speaker. Separate analyses were completed for the sustained vowel and sentence reading samples. Each listener response was coded as either ''accurate'' if it matched the intended gender of the speaker (i.e., accurate for the MFT participants was identification as ''female'' by the listener) or ''inaccurate'' if there was a mismatch with the gender intended by the speaker. For each audio clip, a percent accurate identification was calculated from the responses from the 10 listeners; an overall group mean identification accuracy for both the MFT and the control groups was calculated. Additionally, a 2 × 2 contingency table was constructed with the columns representing the two speaker groups (MFT and control) and the two rows representing ''accurate'' and ''inaccurate'' identification. For the contingency table, a listener was considered accurately identified if eight or more listeners (≥80%) accurately identified the intended gender. A *Fisher exact probability test* for a 2 × 2 table was computed for each table (vowel and the Rainbow Passage, respectively) to determine the probability of obtaining a frequency distribution as extreme or even more extreme than the frequency distribution observed.

Intrarater agreement for the perceptual decisions was calculated from the MFT and control samples that were included twice in the listening experiment (100% of the MFT participants and 25% of the controls). Agreement for the control participants was 97.5% for the sustained vowel samples and 100% for the Rainbow Passage. For the MFT participants, agreement was 86.5% for the sustained vowels and 97.8% for the Rainbow Passage. Overall, the exact agreement data indicated that listeners were consistent in their male/female decision for both groups of speakers and for both speech samples.

Results

Description of the MFT sample

All MFT participants reported living 100% of the time in the female gender role. Average length of time spent living in the female gender role 100% of the time was 5.2 years. Five participants (56%) had undergone genital reconstructive surgery, and 100% were taking hormone replacement therapy.

Participants were asked their own perceptions of their feminized voice. As a group, they believed that others perceived their voices as female an average of 85% of the time. Self-ratings of voice femininity on a scale from 1 (masculine) to 10 (feminine) had a mean of 7.6 (SD, 2.2; range, 5–10). Ratings of satisfaction with their voice on a 10-point scale (1 = not satisfied and 10 = satisfied) had a mean of 7.3 (SD, 1.5; range, 4–10). Participants were also asked to describe the method that they used to feminize the voice (some listed more than one method attempted). Two participants reported having seen an SLP or other voice professional, but on a consultative basis rather than for an ongoing therapeutic intervention. Four reported using some form of ''at-home program'' (e.g., books, CDs, etc.). Four participants reported some form of ''self-directed practice'' that was not based on a book, CD, or other guide, but rather on adjustments that they felt they should make. One participant indicated that she did nothing in terms of voice work, stating that she always felt her voice was feminine.

Information about the participants' voice use was also collected in the history questionnaire. The participants were asked if they ever experienced pain, fatigue, strain, or voice loss. These data are summarized in Table 2. Sixty-seven percent of participants reported some type of voice symptoms. Additionally, 67% of participants reported that they frequently used their voice in activities such as singing or excessive talking at work. One participant had a history of smoking but had quit 3 years before participation in the current investigation.

Endoscopic and stroboscopic image analysis

Ratings for individual participants on each parameter are given in Tables 3–5. Raters followed the guidelines for the SERF as offered by Poburka.[28] The right and left vocal fold edges were generally symmetrical in terms of the extent traveled away from midline (36% and 33% of the total width of each vocal fold, respectively). For this rating, the SLPs chose a distance representing 0–20% (scale value = 2), 21–40% (scale value = 4), 41–60% (scale value = 6), 61–80% (scale value = 8), or 81–100% (scale value = 10) of the width of the vocal fold. For the mean calculation here, the scale values were converted to 20%, 40%, 60%, 80%, and 100%. This same scaling was used for the mucosal wave parameter. The mucosal wave of the right and left vocal folds traveled a distance that was on average 41% and 34% of the width of each vocal fold, respectively. Extent of supraglottic activity during voice production was rated for the right and left ventricular folds separately (i.e., extent of movement toward midline). Additionally, the SLP raters judged the extent of supraglottic constriction in the anterior-posterior (AP) dimension with separate ratings for anterior constriction (i.e., arytenoids moving anteriorly) and posterior constriction (i.e., pedicle of epiglottis bulging posteriorly). The extent of supraglottic constriction was scaled from 0 (no constriction noted) to 5 (substantial constriction). All the MFT participants were noted to have some degree of supraglottic constriction of both the left and right ventricular folds (mean right ventricular fold rating = 1.9; left = 2.0). Eight of nine participants had some degree of bulging of the base of the epiglottis during phonation (not present during quiet breathing) with a mean

Table 2. Voice Use Information of MFT Participants

Participant	Pain	Fatigue	Strain	Loss	Substantial Voice Use?	Smoking History
1					Occupation	Never
2			X		No	Never
3					Occupation	Never
4	X	X	X		Singing	Never
5	X	X	X		Occupation	Never
6	X	X	X		Occupation	Never
7	X	X	X		No	42 y (quit 3 y before study participation)
8		X		X	Karaoke	Never
9					No	Never
Summary (%)	44	56	56	11	67	11
Frequency	(4/9)	(5/9)	(5/9)	(1/9)	(6/9)	(1/9)

rating of 1.4. Raters were asked to indicate any nonvibrating areas of the vocal folds. One participant (participant 4) had a nonvibrating portion of the right and left vocal folds located on the posterior portion of both vocal folds that represented 20% of the superior posterior surface of each vocal fold.

Eight of nine (89%) participants had vocal folds that vibrated on the same vertical plane (i.e., considered normal). Phase closure of the vocal folds was variable among the participants. Four (44%) participants were rated as having a phase closure relationship of 66%/33% open-to-closed ratio, which was considered to be normal (Table 4). Four others (44%) presented with a 90%/10% open-to-closed ratio reflecting an open-closed relationship that is skewed toward ''open.'' One (11%) participant presented with a 33%/66% open-to-closed ratio; this is an open-closed relationship skewed toward ''closed.'' Seven (78%) participants had vocal fold phase symmetry 100% of the time; one (11%) had vocal folds that vibrated symmetrically 80% of the time and another (11%) 60% of the time. Seven (78%) participants had vocal folds that vibrated regularly 100% of the time; two participants (22%) had vocal folds that vibrated regularly 80% of the time.

Participants presented with a variety of glottal closure patterns (Table 5). Four (44%) participants had a posterior gap during phonation. Two (22%) participants had complete glottal closure during sustained /i/. An hourglass formation, anterior gap, and longitudinal (incomplete) gap, respectively, were seen in one participant each (11% each). Six participants had thick mucus pooling on the vocal folds. The raters described this as ''thick'' or ''stringy'' mucus that often spanned the glottis during vocal fold vibration. Laryngeal height adjustments (upward) during phonation at a modal pitch were observed in eight (89%) participants. During modal pitch phonation, two (22%) participants demonstrated pharyngeal tension, whereas the remaining seven (78%) participants had none.

Perceptual ratings of voice

Listeners accurately identified speaker gender for 100% of the control participants (male and female) based on acoustic recordings of the Rainbow Passage. Accuracy of gender identification for the controls remained high for the sustained /i/ productions as well (89% for females and 100% for males). Gender identification accuracy was notably lower

Table 3. Ratings of Glottal and Supraglottal Movement During Sustained /i/ at Modal Pitch and Loudness

Participant	Amp (R VF) (%)	Amp (L VF) (%)	MW (R VF) (%)	MW (L VF) (%)	SGC (R)	SGC (L)	SGC (A)
1	40	40	40	60	2	2	1
2	20	20	40	20	3	3	1
3	40	40	50	50	1	1	0
4	20	20	20	20	3	3	2
5	40	40	40	40	2	2	2
6	40	40	40	40	1	1	1
7	20	20	40	20	2	1	2
8	40	40	40	40	1	1	2
9	60	40	60	20	2	4	2
Mean	36	33	41	34	1.9	2.0	1.4
SD	13	10	11	15	0.8	1.1	0.7

Abbreviations: Amp, amplitude; MW, mucosal wave; SGC, supraglottic contraction; VF, vocal fold; R, right; L, left; A, anterior.

Table 4. Features of Vocal Fold Position and Movement During Sustained /i/ at Modal Pitch and Loudness

Participant	Vertical Level	Phase Closure	Phase Symmetry (%)	Regularity (%)
1	on-plane	66%/33%	100%	100%
2	on-plane	33%/66%	100%	80%
3	on-plane	66%/33%	100%	100%
4	on-plane	90%/10%	100%	100%
5	on-plane	66%/33%	100%	80%
6	on-plane	90%/10%	100%	100%
7	on-plane	90%/10%	60%	100%
8	off-plane	66%/33%	80%	100%
9	on-plane	90%/10%	100%	100%

for the nine MFT participants (Table 6 includes percent accurate identification per participant for each speaking task). Four (44%) were judged to be female based on the second sentence of the Rainbow Passage, whereas the remaining five participants were judged to be male. Gender identification accuracy dropped to 22% for the MFT participants (two of nine participants) based on sustained vowel samples.

To evaluate whether there was a statistical difference in the proportion of participants in the MFT and control groups who were accurately identified in terms of gender, 2 × 2 contingency tables were constructed for the vowel and the Rainbow Passage data, respectively. A *Fisher exact probability test* was computed using the distribution in each contingency table to evaluate the null hypothesis (H_0) that accuracy of gender identification does not vary as a function of participant group (alternative hypothesis: accuracy of gender identification does vary significantly depending on which participant group a person belongs to). Using the *Fisher exact probability test* for the vowel samples, the probability of obtaining cell frequencies as extreme or even more extreme than those actually observed was 0.001. For the Rainbow Passage, the computed probability was 0.004. These probability values are small, leading to the rejection of H_0 and conclusion that gender identification accuracy is higher for the controls for both the vowel and the reading samples.

Fundamental frequency

The F_0 mean and standard deviation for each MFT participant producing sustained /i/ and the reading passage are listed in Table 6. The percentage of listeners identifying each speaker as female is also reported to help depict the relationship with F_0. Mean F_0 was 189 and 170 Hz for the sustained vowel and sentence reading, respectively. There does appear to be a trend (more apparent in reading than sustained vowel) for those MFT participants who are identified as female to have a higher mean F_0, although given the small sample size, it is difficult to draw a firm conclusion. For the sustained vowels, the three speakers with ≥ 60% gender identification rate had a mean F_0 of 198 Hz compared with 184 Hz for the other seven speakers with identification rates ≤ 30%. For the reading passage, four speakers had a 100% accurate gender identification rate, whereas the rest were ≤ 10%. These four had a mean F_0 of 186 Hz versus a mean of 157 Hz for the other six. There were exceptions to this trend, however. For the sustained vowel stimuli, for example, the participants with the two highest F_0s (participants 1 [214 Hz] and 7 [239 HZ]) had low gender identification rates. For the reading passage, participant 5 had only the sixth highest F_0, but a 100% accurate gender identification; two others (participants 6 and 7) had 0% accurate gender identification but had F_0s that were 5–15 Hz higher than that for participant 5.

Discussion

The purpose of this study was to describe the laryngeal presentation of MFT speakers using their feminine voice. The motivation for the study was twofold: (1) to provide information on laryngeal activity in this population that might inform about how an anatomically male larynx is used by MFT persons to generate their feminine voice and (2) to provide more direct data about hyperfunctional voice, or lack thereof, in MFT persons.

Table 5. Other Notable Features of the Larynx and Pharynx From the Endoscopic and Stroboscopic Examination

Participant	Glottal Closure	Excess Mucus Present	Laryngeal Height Adjustment	Pharyngeal Tension Modal
1	Posterior gap	No	Moderate	None
2	Complete	Yes	Moderate	None
3	Posterior gap	Yes	Moderate	None
4	Posterior gap	No	Minimum	None
5	Posterior gap	No	Minimum	Some
6	Anterior gap	Yes	Moderate	None
7	Longitudinal gap	Yes	Minimum	Some
8	Complete	Yes	None	None
9	Hourglass	No	Moderate	None

Table 6. Mean Fundamental Frequency (SD) of Sustained Vowel and Rainbow Passage and Percent Accurate Gender Identification of MFT Participants

	Sustained Vowel /i/		Second Sentence of Rainbow Passage	
Participant	Mean (SD)	Percent Accurate Gender Identification	Mean (SD)	Percent Accurate Gender Identification
1	214 (2.2)	30	198 (22.9)	100
2	175 (2.5)	0	156 (51.7)	10
3	190 (1.2)	60	187 (64.1)	100
4	189 (1.5)	90	195 (48.4)	100
5	216 (8.4)	90	165 (26.47)	100
6	165 (1.0)	0	170 (22.6)	0
7	239 (2.3)	0	178 (34.6)	0
8	142 (1.3)	0	147 (37.9)	0
9	169 (1.6)	20	132 (16.8)	0
Group	189 (2.4)	22	170 (36.6)	44

Abbreviation: SD, standard deviation.

Laryngeal presentation of MFT speakers using their feminine voice

Three trends were apparent in the SLP raters' observations of the larynges of the nine MFT persons: (1) glottal closure was incomplete in most speakers, although the actual shape of the glottal opening varied somewhat across speakers; (2) the phase closure ratio (open/close) tended toward more ''openness'' than might be expected from a group of speakers with an anatomically male larynx; and (3) the majority had indications of vocal hyperfunction. Each of these three findings is discussed in more detail below. Other features such as amplitude of vibration, extent of mucosal wave, and phase symmetry were within normal limits when compared with the values described in Kendall.[22] Additionally, regularity of vibration, vertical plane position of the vocal folds, and presence of nonvibratory portions of the membranous vocal folds were rated as normal for all or nearly all the MFT participants.

Glottal closure. Seventy-eight percent (seven of nine) of the MFT speakers presented with incomplete glottal closure with four presenting a posterior gap and one each presenting with an anterior, longitudinal, or hourglass gap. Most biologically male speakers are expected to have complete glottal closure when speaking. Kendall[22] found that 71% of males were consistently rated as speaking with complete glottal closure when observed with videostroboscopy and high-speed laryngeal imaging. Similarly, Södersten and Lindestad[29] found that 67% of males demonstrated complete glottal closure when phonating at habitual pitch with normal loudness. The nine MFT persons in the present study demonstrated just the opposite with more than 70% showing an open glottis and less than 30% having a closed glottis.

Biologically female speakers often present with a posterior glottal chink, ranging in incidence from ~35% (when using a soft and loud voice) to ~95% (at habitual pitch with normal loudness) in various studies.[23,29–31] This glottal configuration has been associated with breathiness that is more likely to be perceived in the voice of females.[29] Given what is known about glottal closure patterns for both males and females, it appears that many of the MFT speakers in this study are demonstrating a closure pattern that is more consistent with females rather than with males. The MFT speakers with a posterior and perhaps the longitudinal glottal gap (five of nine), in particular, fit with the description of the biological female larynx presentation. Because we do not have laryngeal examination data before their attempts at voice feminization, it is not known whether these individuals were using less-than-complete glottal closure all along, or if the more open glottal configuration was adopted during voice feminization. However, given participant reports of normal male voice before transitioning, it is presumed that these nine individuals would have followed the expected distribution of ~70% showing complete glottal closure before transitioning. It very well may be that some of the MFT individuals were affecting a more open glottis in an attempt to achieve the feminine voice.

The MFT individuals who had an anterior gap and the hourglass configuration deserve mention. An anterior glottal gap has been identified as a result of vocal fatigue in biological males and females who did not initially present with an anterior gap.[31,32] In videostroboscopic examinations of biological males who had a history of laryngeal fatigue, an anterior gap was observed in 28% of speakers.[32] The MFT speaker in the current investigation who presented with an anterior gap (participant 6) reported a history of vocal fatigue when speaking, which has been cited as a possible source of an anterior gap.[31] Similarly, an hourglass glottal gap is often associated with vocal fold tissue changes such as midmembranous edema or vocal fold nodules, which may result from vocal hyperfunction.[33] In the MFT participant demonstrating the hourglass opening, there was no observable tissue change noted by the SLP raters. However,

tissue change is not a prerequisite for presentation with an hourglass glottic opening. Murry et al[34] found that some males and females with normal voice demonstrate an hourglass or spindle glottis during high-frequency modal and falsetto phonation with the implication that this may not be abnormal (although maybe not ideal) when pitch is adjusted upward. Although acoustic analysis of each speaker's male and female voice was not part of the present study, it was clear to the investigators that the MFT participant with the hourglass glottis was producing voice at a higher pitch when using the feminine voice.

Phase closure ratio. A 66–33% ratio of vocal fold phase closure (i.e., 66% open and 33% closed) is expected of normal nonbreathy speakers as indicated on the SERF.[28] Kendall's[22] laryngeal imagining data indicated an average open phase of 62.3% in normal speakers, supporting the notion that a 2/3 open to 1/3 closed phase ratio should be expected. Of the nine speakers in the present study, four demonstrated this phase closure ratio. Interestingly, three of these speakers also had a posterior glottal gap and were in the group of only four MFT participants who were consistently perceived as female in the listening experiment. That is, their larynx presented in a manner consistent with what might be seen in anatomic females with normal phase closure ratio and a posterior glottal gap. Again, without pretransition laryngeal imagining data, it is not possible to know if this subset of MFT individuals was predisposed to this combination of laryngeal activity before attempting voice changes or if this was a newly acquired set of laryngeal behaviors when they feminized the voice.

Four others demonstrated a 90%/10% phase closure ratio (i.e., the vocal folds were open for nearly all the glottal cycle). Although phase closure relationships greater than ~60% have been reported for males and females during modal phonation,[22] having such a large percentage of the MFT group (44%) demonstrate this large ''open'' ratio suggests that as a group, they may have been attempting some type of laryngeal adjustment to sound feminine. One might expect that a more open phase relationship would result in a breathier voice and one that is perhaps less loud (given the likelihood of subglottal pressure reduction assuming respiratory forces remain unchanged). Slightly breathy voice is regularly mentioned in the MFT voice feminization literature and in the voice alteration products available for purchase within the MFT community. This subset of participants may have been attempting to produce a breathier voice and altered their phase closure ratio in the process. Unfortunately, for three of the four speakers with 90%/10% phase closure ratios, they were consistently perceived as male during the listening experiment. Increased airflow through the glottis might be more often associated with breathy voice, but on its own, this quality change is likely to be inadequate to consistently identify a speaker as female in the absence of other laryngeal/ voice and communication style adjustments.

Indications of vocal hyperfunction. Supraglottic contraction of the left and right ventricular folds during phonation was consistently seen to varying degrees in 100% of participants during the laryngeal examinations. Clinically, this is usually interpreted as an indicator of increased tension and effort[35,36] and for that reason is considered a possible marker for hyperfunctional voice use. In addition to contraction of the ventricular folds toward midline, voice clinicians often look for approximation of the epiglottis and arytenoids (i.e., AP supraglottic constriction) that was apparent in 89% of our MFT speakers. Stager et al[37] found that static left-right supraglottic and AP constrictions are indicative of voice use patterns with excessive muscle tension. In the present study, the left-right and AP supraglottic activity might be an outcome of the MFT participants' attempt to increase speaking fundamental frequency. It might also be that to position the arytenoids and vocal folds to create a glottal gap, as was seen in all but two speakers, some individuals might engage in maladaptive increases in supraglottic muscle activity.

The self-report data from the MFT speakers in the present study also support the notion that many have had, or were currently experiencing, voice symptoms consistent with vocal misuse. Two-thirds of the group reported experiencing at least one or more of voice-related pain, fatigue, strain, or loss. During informal interactions with participants after data collection, several commented on rather significant and persistent voice-related problems, with fatigue being common.

Listener identification of MFT speaker gender

The intent of this study was to report on MFT persons who ''pass'' in their day-to-day interactions. By self-report, the nine participants did so. However, the listening experiment results stand in contrast to the high self-reported passing rates. Whether using the sustained vowel or the second sentence of the Rainbow Passage, gender identification rates were below 50% for the MFT speakers. It may be that high passing rates reported by the MFT participants are accurate for natural communication exchanges where there is more extensive verbal output and visual cues that might help signal the preferred female gender (e.g., clothing, facial/body/hair presentation, and body language). Regardless, even without visual cues, listeners are able to accurately identify non-MFT speakers as either male or female from an audio-only sample.[38,39] Based solely on voice production, only a subgroup of the group of MFT speakers described here could be considered as having a definitely female-sounding voice. The descriptions of the laryngeal presentation are reflective of the convenience sample of MFT individuals who were available in the geographic area, not of MFT individuals for whom there is clear evidence of success at ''passing'' as female based on voice alone.

The four MFT participants who were consistently perceived as female also self-reported higher levels of femininity (means of 9 on the 10-point scale) and satisfaction with their voice (also means of 9 on the 10-point scale) compared with the five who were consistently perceived as male (means of 6 on each parameter). That is, those MFT speakers who reported high satisfaction with the voice and high voice femininity also tended to be perceived by others as female. This is consistent with the results of McNeill et al[40] for other MFT speakers. These same four individuals also tended to have a higher mean speaking F_0. The available literature regarding acoustic features of MFT voice are clear that increasing F_0 alone is generally not sufficient to result in a passing female

voice.[10,39,41] However, increasing F_0 is part of the adjustment that seems necessary for many, and a gender-ambiguous F_0 of 150–160 Hz is often targeted.[14,38] In the current investigation, the MFT participants who were consistently perceived as female had a mean F_0 well above the gender-ambiguous range in both the vowel and Rainbow Passage productions. The five speakers who were consistently perceived as male had mean F_0 that tended to be lower than those who were consistently perceived as females, but still within the gender-ambiguous range. Eight of nine MFT participants in this study were within 150–160 Hz for the sustained vowel; yet only three had gender identification rates ≥ 60%. Likewise, for the sentence reading, seven of nine were within the suggested hertz range, but only four were consistently perceived as female. Although the number of subjects is limited, the data are consistent with the literature suggesting that an increased F_0 is one potentially important factor in the voice feminization process, but on its own, it may not be sufficient to be perceived as female from a voice sample alone.

It is interesting to note that the four MFT speakers who presented with a posterior glottal gap in this investigation were consistently perceived as female during the Rainbow Passage portion of the perceptual experiment. Although no firm conclusions can be drawn because of the limited number of participants here and the fact that pretransition data were not obtained, it is tempting to speculate that the posterior glottic gap may be an advantageous laryngeal configuration for an MFT person when working toward a female-sounding voice. If this is confirmed in subsequent studies, it suggests a very specific therapeutic target in terms of laryngeal activity for which biofeedback using laryngeal imaging procedures could be of potential benefit.

There were a few other potentially interesting trends noted when comparing the MFT participants who were identified as female to those identified as male in the listening experiment. Of note, those perceived as female had a lower incidence of thick mucus pooling on the folds or in the larynx (25% vs 80% in those perceived as male), and they also reported high voice use as part of their work-life or social-recreational activities (74% vs 40%). Although only speculative, together these might suggest that those perceived as female were more aware of caring for their voice (i.e., increased hydration), and perhaps they had high motivation, need, and practice opportunities to refine their voice. Presumably extended attempts to use the feminine voice as part of their job would result not only in ''practice time'' with the voice but would also provide these women with natural feedback from coworkers or others, which could help shape what they do with their voice and communication. Finally, the four MFT participants perceived as female in the listening experiment had an average age that was nearly 13 years less than the five perceived as male (43 vs 56 years). Future studies exploring the relationship between age and feminization of the voice in MFT persons are needed to determine whether age is a significant factor in this process.

Those MFT participants perceived as female did not distinguish themselves from those perceived as male in terms of voice symptoms of pain, fatigue, strain, and voice loss. Two of the four women who were perceived as female reported no negative voice symptoms; the other two both reported pain, fatigue, and strain. This suggests that at least some of those with a female-sounding voice may have been generating it in a less-than-ideal manner.

Summary, conclusions, and study limitations

Most MFT persons in this study produced their feminine voice with some type of glottal gap, with a posterior gap predominating. A phase closure relationship skewed toward a greater percentage of ''open'' time also was common. Excess supraglottic constriction was noted for all but one of the participants. This may indicate vocal hyperfunction during feminine voice production that is consistent with the symptoms of vocal fatigue, pain, or voice loss from nearly all the participants.

The data suggest that posterior glottic gap and less complete glottal closure are two common laryngeal observations as individuals with anatomically male larynges attempt to produce a feminine voice. It is not clear from the present study whether these are necessary or beneficial, but they may be. In an attempt to adjust voice quality toward slight breathiness and limited glottal fry, for example, both a glottal gap and more open phase time are logical. However, the perceptual rating task was limited to gender identification; so it is not known whether there was a specific voice quality (or other) change associated with specific glottal gap or phase closure relationships. A larger participant pool and perceptual task designed specifically for that purpose are needed to investigate this possibility further.

The indications of potential hyperfunction from the imaging data and voice history deserve further mention. Some in the MFT community may be able to attain an acceptable female-sounding voice without professional help. However, even among the four who would be considered successful with voice feminization based on their self-report and the listener perceptual study, two had indications from endoscopy (excess supraglottic activity) and self-report (voice pain, fatigue, and strain) that most clinicians consider reflective of unhealthy voice use consistent with excess phonatory effort. None of the participants here had sought ongoing professional voice help in the transition process. They were essentially self-taught or had received some guidance from others in the MFT community through purchased materials (books, CDs, etc.), Internet contact, or face-to-face contact with other MFT persons. Direct intervention by a knowledgeable voice professional might prove helpful in limiting voice symptoms and maximizing vocal change (and other communication behaviors) that favors perception of the MFT speaker as a woman. Endoscopic and stroboscopic baselining of laryngeal behaviors and ongoing use of the visual feedback during therapy could be helpful in identifying maladaptive behaviors and establishing new ones that promote the perceptual target, namely a feminine voice. Again, additional work that tracks these women from the pretransition through the posttransition process using laryngeal imaging procedures along with other measures (perceptual, acoustic, etc.) is needed to help determine not just whether professional intervention is helpful but also to identify the specific changes that occur. By doing the latter, more specific therapeutic targets and treatment strategies might be developed to help others.

In addition to the small participant pool size, the group was heterogeneous in terms of age and years since transitioning, both factors that might have some influence on the voice that deserve further investigation. Additionally, although these MFT speakers self-reported as passing, the speech sample obtained for perceptual confirmation of ''passing'' based on voice alone was restricted and may not have been an accurate reflection of extent of passing in daily interactions. Within-participant comparison of an MFT person producing her feminine voice and her ''old'' voice (i.e., male) was considered and initially attempted here. However, several reported that they no longer remembered what their voice used to sound like, and those who could revert back to another voice indicated a lack of confidence that they really had produced their old voice. Longitudinal evaluations through the transition process would be quite informative.

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