Pitch Elevation in Male-to-female Transgender Persons—the Würzburg Approach

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Summary: Objectives. The present study reports objective and subjective voice results of Wendler’s glottoplasty modified by Hagen.

Study design. This is an outcomes research study.

Methods. A total of 21 patients underwent Wendler’s glottoplasty modified by Hagen. Parameters in the follow-up session were laryngoscopy, voice range profile, Voice Handicap Index, Life Satisfaction Questionnaire, and a visual analog scale for individual satisfaction with the voice.

Results. The fundamental frequency was elevated into the typical female fundamental frequency range. Furthermore, an elevation of the lower frequency limit was shown without a reduction of the frequency range. About one third of the population feels affected by the restricted dynamic range. This change of the vocal pitch is seen as part of the voice feminization by some of the patients. The Dysphonia Severity Index as a marker for voice quality was unchanged. Subjective satisfaction with the voice showed a strong correlation with the individual elevation of the pitch.

Conclusion. Wendler’s glottoplasty modified by Hagen is an effective and low-risk method of raising the vocal pitch of male-to-female transgender persons. However, elevated Scores of the Voice Handicap Index indicated that in everyday life, transgender persons continue to feel handicapped because of their voice. Another indicator for the lack of social acceptance and integration is the reduced general life satisfaction in the Life Satisfaction Questionnaire especially in the domain “friends, acquaintances, relatives.” Therefore, a better multidisciplinary therapy concept for voice feminization is necessary.

Key Words: Pitch elevation–Transgender voice–Glottoplasty–Voice feminization–Phonosurgery.

INTRODUCTION

Transsexualism is a problem of gender identity with the individuals being firmly convinced that their psychological gender is the opposite of their anatomic gender. The feeling to live in the wrong body is compelling and, if suppressed, the level of suffering may even lead to suicide. After long and burdensome therapy procedures consisting of medical and psychological treatments, transgender persons obviously wish to be accepted in the society with their new gender role. The voice as a secondary sexual characteristic is an important factor of gender perception. Male-to-female (MtF) transgender persons, in whom hormonal treatment shows no influence on the voice, are often stigmatized by their deep voice betraying their biological gender in everyday life communication. Thus, speech feminization is a very important element in the multidisciplinary therapy of MtF transsexuals. The most important parameter for gender perception of a voice is the fundamental frequency f(0) introduced a classification of typical frequency ranges: male voices typically vary in a range of 80–165 Hz; female voices typically vary in a range of 145–275 Hz. Consequently, there exists an overlap range from 145 Hz to 165 Hz where the fundamental frequency cannot be assigned to one gender uniquely. Beside the fundamental frequency there are other parameters influencing gender perception of a voice. These are, for example, the formant frequencies, which are higher in female persons than in male persons, 6,17,27,28

Further differences between male and female speakers in voice quality include a broad spectrum. The most important aspect of voice quality for MtF transgender persons is breathiness, 14,29–31 Furthermore, frequently mentioned targets in conservative voice therapy are intonation patterns. The relevance of these differences between male and female speakers for gender perception is discussed controversially. Some authors reported about an important role of intonation and prosodic characteristics in conservative voice therapy with MtF. In contrast, Hancock et al could not show any differences in intonation patterns between male, female, MtF transgender, and female-to-male transgender speakers.

THERAPY OF THE TRANSGENDERED VOICE

Conservative voice therapy is the first step in voice feminization. In the topic-related literature, some data sets show that for some persons, a successful feminization of the voice is possible with conservative voice therapy only. But not all patients are able to reach a satisfying feminine voice with conservative voice therapy only, and some develop functional disorders because of the high tension in the larynx. Even if the pitch alteration is sufficient, the male voice may appear in uncontrolled and emotional situations like yawning, coughing, and laughing.

If there is no satisfying result with conservative voice therapy, surgery may be offered. In principle, there is a variety of techniques to elevate vocal pitch. Surgically, increase of the tension of the vocal cords with a cricothyroid approximation (CTA) is
an option. CTA has the advantage not to surgically interfere with the internal structures of the larynx. Consequently, the risk of voice irregularities after the surgery appears to be low.\textsuperscript{46} Many authors describe good early results,\textsuperscript{33,39,40} but there are also reports of a loss of the tension in the long term, necrosis of cartilage, and damages on the larynx because of the high tension.\textsuperscript{43,44} Neumann and Welzel\textsuperscript{45} modified the CTA via miniplates. Long-term results showed a sufficient elevation of vocal pitch, but for about 30\% of the patients, there was only a slight rise of the pitch and, in two cases, even a decrease of the fundamental frequency. Kanagalingam et al\textsuperscript{4} combined a CTA with a subluxation of the cricothyroid. After good early results, however, the fundamental frequency of the patients decreased within 6 month from 191 Hz to 175 Hz in median.

Another possibility for pitch elevation is the reduction of the mass of the vocal cords. Published results of this intervention are rare and seemed to be inhomogeneous. Orloff\textsuperscript{47} reported on 31 MtF after “laser-assisted voice adjustment.” The fundamental frequency was elevated about 26 Hz in average, but there were three patients without any change of vocal pitch and three patients with a deeper voice after laser-assisted voice adjustment. Koçak et al\textsuperscript{48} could show good long-term results in eight MtF patients with a laser-reduction glottoplasty.

A third established method for pitch elevation is to shorten the vibrating length of the vocal folds creating a new anterior commissure. This “glottoplasty” in endoscopic approach was first described by Wendler.\textsuperscript{49} Gross,\textsuperscript{5} Remacle et al,\textsuperscript{50} and Mastronikolis et al\textsuperscript{51} showed good long-term results with a postoperative fundamental frequency of about 200 Hz. Anderson\textsuperscript{52} reported on positive results with a modified technique without any sutures. The advantage of this surgery is the low invasiveness without an external approach. One disadvantage of this method is the irreversibility of the measure and the risk of postoperative hoarseness. Additionally, the frequency range\textsuperscript{53} or the dynamic range\textsuperscript{54} might be restricted after surgery.

Another very invasive concept is the “feminization laryngoplasty,” which includes the excision of the anterior thyroid ala and vocal folds.\textsuperscript{50,51} Thus, the purpose is to change the shape of the vocal tract and to elevate, in addition to the fundamental frequency, the formant frequencies too. Thomas and Macmillan\textsuperscript{51} investigated long-term results of 76 patients with a significant elevation of the vocal pitch. A total of 25 patients were very dissatisfied with the result and underwent a revision surgery despite this very complex process.

The aim of the present study is to report a series of 21 patients after Wendler’s glottoplasty modified by Hagen. In this modified technique, the new anterior commissure is stabilized by two to three 4-0 vicryl sutures. Additionally, a voice rest for several weeks is induced by injecting botulinum toxin in the vocal muscle on both sides. We investigated the success of the surgery regarding objective voice parameters and the subjective satisfaction with the result.

**INDIVIDUALS, MATERIALS, AND METHODS**

All 37 MtF transgender patients who underwent glottoplasty in Würzburg between December 2005 and April 2013 were invited to attend a follow-up session in the University Hospital Würzburg, Department of Otorhinolaryngology, Plastic, Aesthetic, and Reconstructive Head and Neck Surgery without any exclusion criteria. A total of 25 patients could be tracked due to a variety of reasons including change of addresses, names, and strict German legislation concerning data protection. Two patients refused our invitation because of personal problems, and two other patients felt to be a woman completely and did not want to be reminded on the transition anymore.

**SURGICAL PROCEDURE**

For a permanent elevation of the vocal pitch, a glottoplasty based on the endoscopic technique of Wendler\textsuperscript{47} modified by Hagen was applied. The endoscopic surgery was performed under general anesthesia. The Kleinsasser endoscope was adjusted to the anterior commissure. In the area of the anterior third of the vocal folds and the anterior commissure, the epithelium was resected. The adaption of the anterior third of the vocal cords was fixed by vicryl 4.0 sutures. In 11 cases, the anterior commissure was fixed with 3 sutures, in 9 cases with 2 sutures, and in 1 case with 1 suture only. A voice rest for several weeks was induced by injection of 25 I.E. botulinum toxin into vocal muscle on each side according to Hagen’s modifications of the Wendler technique. Figure 1(A–F) shows individual steps of the glottoplasty. If desired, an Adam’s apple reduction according to Wolfort et al\textsuperscript{55} was performed in the same session.

**OBJECTIVE EVALUATION**

One method of choice to examine the larynx with the new anterior commissure was the video laryngoscopy. The examination was carried out using a 90° Hopkins optics (8707 DA, Karl Storz, Tuttingen, Germany) or, in case of gagging reactions, using a nasal endoscope (ENF VQ, “chip on the tip,” Olympus, Shinjuku, Japan).

The most often used method to collect objective voice parameters is the voice range profile. The collected voice data are fundamental frequency, frequency range, dynamic range, maximum phonation time, and the dimensionless Dysphonia Severity Index as a parameter for voice quality.\textsuperscript{53–55} In the present study, the voice range profile was performed based on the standard method for German speakers\textsuperscript{55–57} using the software DiVAS Stimnumfangsprofil 2.4.53 of XION (XION-medical, Berlin, Germany).

**SUBJECTIVE EVALUATION**

To objectify the subjective voice perception of the individuals, the Voice Handicap Index\textsuperscript{58} was used, which is an established and validated instrument in the German version.\textsuperscript{59} To examine general life satisfaction for those having completed the transition from male to female, we used the Life Satisfaction Questionnaire (FLZ).\textsuperscript{60} To examine subjective satisfaction with voice, a 10-cm visual analog scale (VAS) from 0 (“very dissatisfied”) to 10 (“very satisfied”) was used.

**STATISTICAL ANALYSES AND GRAPHS**

For statistical analyses and graphs, IBM SPSS Statistics (IBM SPSS Statistics Version 21, IBM, Armonk, NY, USA) was used. Pre- and postsurgery data were analyzed with the Wilcoxon
signed-rank test. Comparison of individual elevation of the vocal pitch between patients with two and three sutures was done with the Mann-Whitney $U$ test. The distribution into the fundamental frequency ranges was analyzed with the McNemar test. Statistical comparison of the Voice Handicap Index and the FLZ with validated control groups was performed with the one-sample $t$ test. All correlations were analyzed with the spearman correlation.

RESULTS

This series included 21 patients. Out of those patients, 18 agreed to attend a follow-up session in the Department of Otorhinolaryngology, Plastic, Aesthetic, and Reconstructive Head and Neck Surgery of the University Hospital Würzburg, and three patients agreed to do a follow-up by questionnaires only. Four of them had a previous cricothyroidopexy without satisfying results. In 11 cases, the glottoplasty was combined with an Adam’s apple reduction plasty. Population data of the 21 patients are listed in Table 1. The postoperative examination period ranged from 3 month up to 78 month. In all of the 21 cases, there were no major complications. For patient no. 3, a revision surgery was necessary because the synechia was only on the mucosal level. Within the scope of the follow-up sessions, we had to admit on laryngoscopy that the synechia of patient 12 had not lasted and the original anterior commissure had persisted. The cosmetic results of all 11 patients who underwent Adam’s apple reduction plasty were satisfying. The number of sutures had no significant influence on the objective voice parameters.

OBJECTIVE VOICE PARAMETERS

Table 2 summarizes preoperative and postoperative data from the voice range profile including $f(0)$, Dysphonia Severity Index, dynamic range, and frequency range as well as individual subjective evaluation data.

Figure 2 shows the comparison of pre- and postoperative objective voice data regarding fundamental frequency, frequency range, lower frequency limit, dynamic range, and Dysphonia Severity Index.

Comparison of pre- and postoperative data of the fundamental frequency ($n = 21$; Figure 2A) showed an elevation of the vocal pitch for all patients except for patient no. 12. Preoperatively, the median of the fundamental frequency was 132 Hz (110–160 Hz; standard deviation [SD] = 16.4 Hz). The postoperative median of the fundamental frequency was 170 Hz (130–215 Hz; SD = 24.3 Hz). The elevation of the fundamental frequency was significant ($P < 0.001$). There was no correlation between the elevation of the fundamental frequency and the number of conservative voice therapy sessions (Spearman rank correlation $r = −0.169$; $P = 0.464$; data not shown).

The patients were classified in five groups regarding the elevation of the fundamental frequency (Figure 3). Only patient no. 12 showed no elevation of the vocal pitch. Three patients showed a small elevation of the vocal pitch (<20 Hz), four patients showed a moderate elevation (20–39 Hz), five patients showed a strong elevation (40–59 Hz), and eight patients showed a very strong elevation of the fundamental frequency (≥60 Hz).

Analysis of pre- and postoperative fundamental frequency range, shown in Figure 2B, showed no difference ($P = 0.653$). Preoperatively, the median was 308 Hz (145–502 Hz; SD = 88.2 Hz). Postoperatively, the median was 282 Hz (75–695 Hz; SD = 151.5 Hz).

The lower frequency limit, illustrated in Figure 2C, showed a significant elevation from a median of 85 Hz (65–140 Hz; SD = 23.7 Hz) preoperatively and a median of 113 Hz (83–190 Hz; SD = 27.0 Hz) postoperatively ($P = 0.005$). There was no change for the upper frequency limit ($P = 0.981$; data not shown).

The dynamic range, illustrated in Figure 2D, showed a significant decrease in comparison of pre- and postoperative data ($P = 0.012$). Before surgery, the median was 42.5 dB (33–56 dB; SD 6.8 dB). After surgery the median was 37 dB (21–47 dB;
SD = 7.2 dB). The minimum and maximum intensities showed no difference (data not shown).

The comparison of pre- and postoperative data regarding the dimensionless Dysphonia Severity Index, illustrated in Figure 2E, showed no change (n = 14; P = 0.125). Preoperatively, the median was 2.6 (−0.4 to 5.4; SD = 1.57). Postoperatively, the median was 2.1 (−0.7 to 5.3; SD = 1.71).

SUBJECTIVE EVALUATION OF SUCCESS
Table 3 shows the mean values of the VHI domains “functional,” “physical,” and “emotional” plus the VHI score compared with a German control group from Weigelt et al. All mean values of our patients were below the check values from Weigelt et al (P < 0.001). Figure 4 shows the classification of the voice handicap into the degrees of severity according to the classification of the German Society of Phoniatrics and Pedaudiology. The FLZ showed a significant reduction of the general life satisfaction with a mean “stanine” score of 3.68 compared with the validated and age-matched check values (P = 0.026). The deficiencies in the category “friends, acquaintances, relatives” were significant (P = 0.016; data not shown).

The VAS “satisfaction with voice” showed a median of 6.1 cm (0–9 cm) and the VAS “feminity of the voice” showed a median of 5.3 (0–9.2 cm). There was a very strong correlation between the VASs (r = 0.904; P < 0.001; data not shown).

The correlation of the 10-cm VAS “satisfaction with voice” with the postoperative fundamental frequency (r = 0.577; R² = 0.377; P = 0.006) is shown in Figure 5A. The correlation with the VAS and the individual difference of the pre- and postoperative fundamental frequency (r = 0.663; R² = 0.403; P = 0.001) is illustrated in Figure 5B.

DISCUSSION
The present study describes the outcomes of Wendler’s glottoplasty modified by Hagen in 21 MtF transgender persons. Except for one patient, an elevation of the vocal pitch could be achieved. Similar to the results of Gross, Remacle et al, and Mastronikolis et al, Wendler’s glottoplasty in the modified technique of Hagen also proved to be an effective and low-risk method to raise the fundamental frequency of MtF transgender persons, which is the strongest parameter for gender perception.  

Regarding the typical fundamental frequency ranges used by Oates and Dacakis after surgery, the median fundamental frequency of the present study population was in the female frequency range (>165 Hz). The voice pitch of seven patients was in the overlap range (145–165 Hz) where the pitch cannot...
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Notes: The following are shown: the preoperative (f(0) pre) and postoperative (f(0) post) fundamental frequency, preoperative (f(0)min pre) and postoperative (f(0)min post) minimum frequency, pre- and postoperative frequency range, pre- and postoperative dynamic range, pre- and postoperative Dysphonia Severity Index (DSI), the postoperative Voice Handicap Index (VHI), and the standards of nine from the score of the Life Satisfaction Questionnaire (FLZ stanine). Missing data in preoperative frequency range, f(0)min, dynamic range, and DSI appeared because of incomplete voice range profiles for patients nos 13, 18, 19, 20, and 21. Partial missing data of patient no 19 are due to external measurement of the voice range profile. For patient no 21, an incomplete postoperative voice range profile from a former follow-up session was used.
be assigned to one gender uniquely. Only one patient remained in the male frequency range. Furthermore, the voice range profile showed no change in frequency range but a significant increased lower frequency limit. This reduction of the low frequencies, also reported by Gross5 and Thomas and Macmillan,51 is part of the feminization effect and leads to a stable higher pitch level also in uncontrolled situations. Similarly, the restriction of the dynamic range could be considered as desired effect in voice feminization because a slight voice is associated with female speakers.15,21,34,64,65 According to the findings of Gross,5 about one third of our patients desired a louder voice.

In voice therapy, especially in MtF transgender persons, there exists a frequently mentioned discrepancy between objective voice parameters and subjective voice perception or satisfaction:13,25,40,66–69

FIGURE 2. Comparison of preoperative and postoperative data regarding (A) fundamental frequency f(0) (P < 0.001), (B) frequency range (P = 0.563), (C) lower frequency limit f0(min) (P = 0.005), (D) dynamic range (P = 0.012), and (E) Dysphonia Severity Index (P = 0.125).

FIGURE 3. Classification of the patients into five groups regarding the elevation of the fundamental frequency. The following categories are shown: "no change of vocal pitch" (0 Hz), "small change of vocal pitch" (elevation of <20 Hz), "moderate change of vocal pitch" (elevation of 20–39 Hz), "strong change of vocal pitch" (elevation of 40–59 Hz), and "very strong change of vocal pitch" (elevation of ≥60 Hz).
analysis of the relationships between objective and subjective evaluation showed that the individual change of vocal pitch is of wider importance for personal satisfaction with the voice than the absolute value of the fundamental frequency. Another important factor for satisfaction is the interpersonal communication, which influences the social integration of transsexual persons. Obviously, the desire of the patients is to pass with their new gender role in society. The wish to acquire a female voice was shown with a strong correlation between the self-assessment of the voice femininity and the subjective voice satisfaction. The more female the persons perceived their own voice, the higher is the subjective satisfaction. But a higher pitch does not guarantee being perceived as female: especially in absence of the visual transport of information like on the telephone, the MtF persons feel stigmatized by being appealed as male. This misperception and irritation of conversation partners may be coresponsible for the deficient social integration of transsexuals in our society. In our report, this lack of integration after completed therapy procedure could be seen by the results of the FLZ especially in the domain “friends, acquaintances, relatives.”

This incomplete rehabilitation of the transgendered voice, which is composed of physiological and social components, is reflected in increased VHI scores. The VHI showed a persistence of the voice handicap although the voice quality, measured with the DSI, was not reduced after surgery.

There were several limitations to the present study. According to most other reports with transgender persons, the number of subjects was relatively small. Despite best efforts, only 21 out of all 37 patients who underwent glottoplasty in Würzburg participated in the follow-up examinations. This may have led to a certain negative selection bias, which may have influenced our results because several patients who were very satisfied with their voice did not want to accept the journey for the follow-up session and to feel again as a patient. Also, there is loss of data within the study: the preoperative voice range profiles were not

<table>
<thead>
<tr>
<th>n</th>
<th>Mean (Patients)</th>
<th>Mean (Control Group)</th>
<th>t Test</th>
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<tbody>
<tr>
<td>“Functional”</td>
<td>21</td>
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<td>1.7</td>
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<td>21</td>
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<td>“Emotional”</td>
<td>21</td>
<td>10.00</td>
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<tr>
<td>VHI score</td>
<td>21</td>
<td>32.29</td>
<td>5.2</td>
</tr>
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</table>

FIGURE 4. Classification in degrees of severity of the voice handicap according to the classification of the German Society of Phoniatrics and Pedaudiology. The categories are “no handicap” (25th percentile, VHI score = 0–14), “low handicap” (50th percentile, VHI score = 15–28), “middle handicap” (75th percentile, VHI score = 29–50) and “strong handicap” (100th percentile, VHI score = 51–120).

FIGURE 5. Correlation between the visual analog scale (VAS) “voice satisfaction,” and (A) the postoperative fundamental frequency and (B) the individual elevation of vocal pitch.
complete for all patients. The postoperative voice range pro-
files of patient nos. 19 and 20 were done by external ear, nose, and
throat doctors. For patient no. 21, a voice range profile of a
former follow-up session was used. The population of our study
was very inhomogeneous regarding intervals since surgery and
because of the number of conservative voice therapy sessions and
former surgical intervention. Four patients had already un-
dergone CTA in other departments. Additionally, some of the
patients continued smoking after surgery.

Hence, in the future, a holistic treatment concept is neces-
sary for the feminization of voice and communication. Conser-
vative voice therapy is obligatory for all patients. The
attempt of elevating the vocal pitch can be combined with the
work on aspects like breathier and softer voice timbre and
communication training with nonlinguistic parameters. Addition-
ally, conservative voice therapy can help to elevate also the
formant frequencies and consequently feminize not only the
vocal pitch, but also the timbre of a voice. In case of not
satisfying results, phonosurgery should be performed as “sand-
wich therapy” with pre- and postoperative conservative voice
therapies for improving quality, efficiency, and femininity of the
voice.

Finally, a standardized procedure for evaluating therapy success
is necessary. Therefore, a specific and validated questionnaire
for therapy of the MtF transgender voice is of major interest.
Dacakis et al published in 2013 the Transgender Voice
Questionnaire. Actually, there exists a cooperation project with
the Department of Otorhinolaryngology, Plastic, Aesthetic, and
Reconstructive Head and Neck Surgery of the University Hos-
pital Würzburg to translate this questionnaire into German.

To quantify the perception of the transgender voice in every-
day life, an objective and realistic test is preferable. For this
purpose, we developed a test procedure that evaluates the gender
perception of a voice on the telephone.

CONCLUSION

Regarding objective voice parameters, Wendler’s glottoplasty
modified by Hagen is an effective and low-risk method to elevate
the vocal pitch without affecting voice quality. Despite the el-
eviation of the vocal pitch, the patients reported problems in
everyday life. These issues lead to stigmatization and social prob-
lems. Frequently, the situation on the telephone, where the patients
were addressed as male, was mentioned. Therefore, a specific
voice therapy program additional to phonosurgical inter-
vention is necessary.

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