*The Laryngoscope*


# Injection Laryngoplasty as Adjunct Treatment Method for Muscle Tension Dysphonia: Preliminary Findings

Daniel Novakovic, FRACS, MBBS, MPH, BSc; Duong Duy Nguyen, MD, PhD; Antonia Chacon, BAppSc (SpPath) Hons, CPSP; Catherine Madill, PhD, CPSP

**Objectives:** This study examined the effectiveness of injection laryngoplasty (IL) in muscle tension dysphonia (MTD) patients who did not fully respond to voice therapy. It was hypothesized that IL would improve voice quality and voice-related quality of life measures in MTD.

**Methods:** A retrospective review was conducted on 37 patients with a primary diagnosis of MTD who underwent IL following a suboptimal response to voice therapy (mean age = 43.0 years; standard deviation [SD] = 13.4; range = 23 to 71). Outcome measures included laryngoscopic signs of supraglottic constriction, Voice Handicap Index-10 (VHI-10) scores, maximal phonation time, vowel fundamental frequency (F0), standard deviation of F0 (F0SD), harmonics-to-noise ratio (HNR), and smoothed cepstral peak prominence. These were compared between baseline and within 3 months following the IL procedure.

**Results:** There was significant decrease in supraglottic constriction. Mean (SD) of VHI-10 scores decreased from 25.4 (5.7) at baseline to 15.3 (9.3) following IL. This improvement in VHI-10 was observed in patients with and without baseline glottal insufficiency (GI). Mean (SD) of HNR (decibels) increased from 21.1 (5.4) at baseline to 22.8 (4.3) after IL. Only patients with GI demonstrated a significant improvement in HNR from baseline to post-IL. No statistically significant differences in other acoustic measures were observed.

**Conclusions:** IL resulted in positive changes in voice-related quality of life in MTD patients with and without GI. Acoustically, only those with GI demonstrated an increase in HNR following IL. Further studies are needed to examine the effects of IL in MTD.

**Key Words:** Injection laryngoplasty, muscle tension dysphonia, voice disorders, acoustic analysis, voice-related quality of life.

**Level of Evidence:** 4

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## INTRODUCTION

Voice disorders characterized by excessive tension of the laryngeal muscles during phonation have been referred to as muscle tension dysphonia (MTD).[1] In the absence of obvious laryngeal mucosal and neurological lesions, the condition is referred to as "primary" and is believed to result from improper use of the muscles of the larynx in phonation,[2] although its etiology may be multifactorial.[3] Increased muscle tension may also occur secondary to laryngeal pathology[4] as an attempt to compensate for inefficient phonation (often known as "secondary" or "compensatory" MTD).[5] Primary MTD (referred onward as MTD) presents perceptually with suboptimal voice quality (e.g., breathiness, roughness, strain),[6] and laryngoscopic findings may include glottal and supraglottic constriction in the anteroposterior (AP) and/or lateral dimensions.[2,7] Elevated larynx position, perilaryngeal muscle tenderness, and increased suprahyoid muscle tension are other useful clinical diagnostic signs.[4] A previous study found that 40% of patients in voice clinics had presentations of MTD.[8] This condition may contribute to development of vocal fold phonotraumatic lesions such as nodules, polyps, and chronic laryngitis.[4]

Abnormal muscle tension patterns (MTPs) observed laryngoscopically in MTD, such as supraglottic AP and lateral constriction,[7] may be a sign of an underlying glottal insufficiency (GI) that is not obviously related to a neurological origin.[9] Some authors have proposed that incomplete posterior glottal closure that is sometimes seen in MTD might result from antagonistic action between the posterior and lateral cricoarytenoid muscles,[10] whereas others have maintained that abnormal MTPs are the consequence but not the cause of the insufficiency.[9] Therefore, GI presents as a potentially useful treatment target in MTD patients because it can profoundly impact laryngeal function,[11,12] as evidenced by quality-of-life measures,[13,14] voice quality[15] and laryngoscopic characteristics.[16]

Voice therapy is currently the gold standard of treatment for MTD.[17] A range of voice therapy programs and techniques exist to treat MTD, but it is unknown whether



From the Faculty of Medicine and Health, Central Clinical School, The University of Sydney (D.N.), Camperdown; Voice Research Laboratory, Faculty of Health Sciences, The University of Sydney (D.D.N., A.C., C.M.), Lidcombe; and The Canterbury Hospital, Department of Otolaryngology, Head and Neck Surgery (D.N.), Campsie, Australia.

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Send correspondence to Daniel Novakovic, Suite 1, Level 1, 66 Pacific Highway, St Leonards, NSW 2065, Australia. E-mail: daniel.novakovic@sydney.edu.au

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one treatment demonstrates superior effectiveness.[18] Nonetheless, patients with MTD do not always respond to treatment.[19] A previous study found that 29% of patients with functional voice disorders failed to improve after voice therapy.[7] This may be due to a range of factors that render standard behavioral voice therapy ineffective,[20] a lack of diagnostic rigour,[18] problems in diagnosis due to the nonspecificity of laryngeal features,[21] and the similarity in clinical appearance compared to other voice disorders.[22]

Injection laryngoplasty (IL) is a surgical procedure to treat GI by injection of a biocompatible material to augment vocal fold mass and medialize the vibrating edge. Common materials that have been used include autologous fat[23,24] fascia,[25] collagen-based derivatives,[26] calcium hydroxylapatite (CaHa),[27] and hyaluronic acid derivatives.[28] Duration of effect varies across materials, with most ranging from 3 to 12 months, with the exception of autologous fat and fascia, which can last longer.[29] Injection techniques include transcutaneous and peroral approaches under general anesthesia or local anesthesia, which can be performed in an office-based setting.[30] Complication rate is 3% under general anesthesia and 2% for an awake procedure[30] and includes overinjection and superficial injection, both which impair the mucosal wave.[30,31] A review by Sulica et al. found that IL was primarily used to treat vocal paralysis (54%), vocal paresis (21%), vocal fold atrophy (15%), and vocal fold scar (10%).[30]

In populations with GI, previous studies found that IL resulted in improved voice-related quality-of-life measures such as the Voice Handicap Index-10 (VHI-10) and Voice Performance Questionnaire.[32–34] The procedure has been shown to reduce severity of hoarseness, breathiness, and strain, as measured using the grade, roughness, breathiness, asthenia, and strain and Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V) perceptual scales in patients with GI secondary to vocal fold paralysis and bowing.[35] Significant improvement in acoustic voice measures following IL have also been reported, such as reduced Dysphonia Severity Index[36] in patients with GI due to vocal paralysis and presbylaryngis and improved noise-to-harmonic ratio in patients with vocal fold bowing, paresis, paralysis, and scarring.[25] However, there is limited and contradictory evidence on the effects of IL on MTD features in patients with GI. Ziade et al.[37] found a statistically significant reduction of abnormal MTPs after IL in patients with GI due to unilateral vocal fold paralysis and bowing. In contrast, Su et al.[38] found no significant difference in the frequency of abnormal MTPs following medialization surgery in patients with unilateral vocal fold paralysis. To date, no study has examined the effects of IL on MTD that may be associated with, or be a surface presentation of, underlying GI unrelated to vocal fold paralysis/paresis.[9]

The purpose of this study was to review the efficacy of IL in the treatment of MTD that did not fully resolve with voice therapy. It was hypothesized that IL would result in improvement in voice quality and voice-related quality-of-life measures in MTD.

## MATERIALS AND METHODS

This was a retrospective case review of patients who underwent IL performed by a single Ear, Nose, and Throat surgeon with subspecialty fellowship training in laryngology from 2013 to 2018. Permission for the study was approved by Sydney Local Health District Ethics Review Committee, Royal Prince Alfred Hospital Zone (X18-0175 & LNR/18/RPAH/244).

### *Participants*

This study included 37 English-speaking adult patients with a primary diagnosis of MTD who did not resolve after voice therapy and who subsequently underwent IL (mean age = 43.0 years; standard deviation [SD] = 13.4; range = 23 to 71). Nineteen were male (mean age = 40.6 years; SD = 13.8; range = 23 to 69), and 18 were female (mean age = 45.8 years; SD = 13.2; range = 25 to 71). All participants had attended standard voice therapy treatment for at least 3 consecutive months prior to IL procedure.

Diagnostic criteria for MTD included the following: 1) VHI-10 above cutoff value of 11[39]; 2) Abnormal voice quality assessed by a certified practicing speech-language pathologist (SLP); 3) No evident neurological, structural, or mucosal lesions of the larynx; and 4) Laryngoscopic MTPs including AP and lateral constriction. Indications for IL in MTD included the following: 1) SLP referral to an otolaryngologist following an unsatisfactory response of MTD to voice therapy; 2) VHI-10 scores above cutoff value after voice therapy; and 3) Obvious or suspected underlying GI. In those who did not show obvious GI preprocedure, the decision to proceed to IL was made based on VHI-10 score and consultation with SLP about patient's poor response to voice therapy. This study excluded the following: 1) Non-English-speaking and pediatric patients; 2) Coexisting mucosal, structural, or neurological pathology of the vocal folds; and 3) Absent SLP assessment/referral information after voice therapy.

### *Surgical Procedure*

The first author (D.N.) performed all IL procedures. Injection technique was transcricothyroid (awake procedure) or peroral (general anesthesia). All injections were bilateral. Materials included cross-linked hyaluronic acid gel (n = 34, bilateral mean volume = 0.75 mL), autologous fat (n = 2, bilateral mean volume = 1.2 mL), or CaHa (n = 1, bilateral mean volume = 1.2 mL). Average total volume (SD) was 0.8 (0.3) mL (range = 0.4 to 1.6 mL). Final volume judgment was based on straightness of the medial edge of the vocal folds (Fig. 1) and dynamic glottal closure if performed awake.

### *Postoperative Management*

All patients were advised to undertake relative voice rest for 5 days postprocedure. Patients were routinely instructed to continue with SLP-directed voice therapy within 2 to 3 weeks of the procedure.

### *Data Collection and Analyses*

The following information was reviewed at baseline and within 3 months post-IL.

***Glottal Insufficiency and Supraglottic Muscle Tension Pattern.*** De-identified strobolaryngoscopic examination videos were blindly reviewed to identify the presence or absence of GI and supraglottic AP and lateral constriction. Glottal insufficiency was determined by estimating the percentage of closed phase relative to the whole vibratory cycle and was deemed to be present with <1/3 closed phase at modal phonation. It was used as a predictive factor to compare voice outcome measures. The AP and lateral constriction were evaluated based on criteria documented by Morrison and Rammage[2] and Koufman and Blalock[7] and rated on a 4-point scale (0–3) based on the length (AP) or width (lateral) of vocal fold being obscured (Fig. 2). Twelve videos (30%) were reevaluated for calculating intrarater reliability.

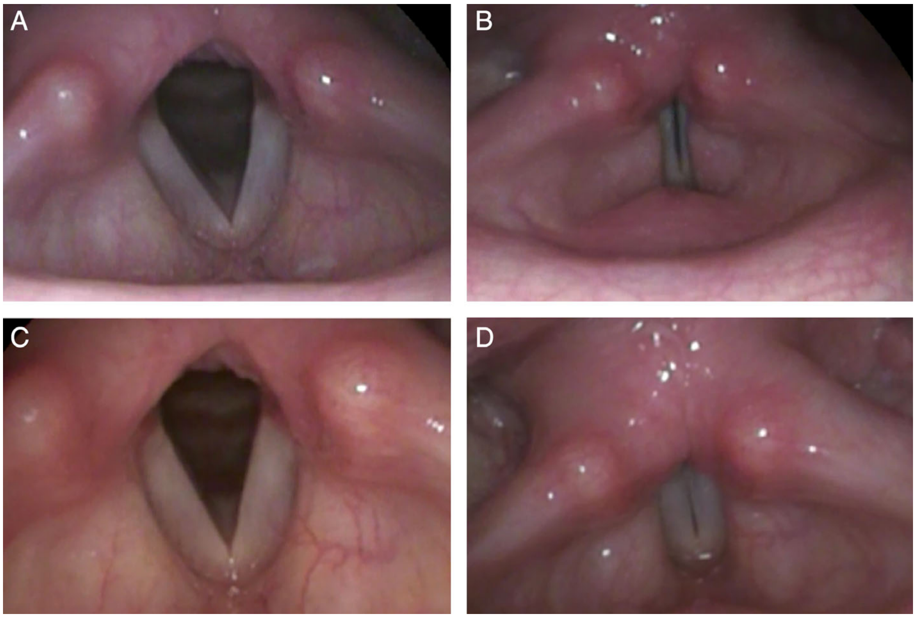


Fig. 1. Female patient with glottal insufficiency before (A and B) and 2 months following (C and D) bilateral injection laryngoplasty.

***Voice Handicap Index-10.*** The VHI-10 is a validated patient-reported assessment tool that evaluates the functional, physical, and emotional impact of voice disorders.[40] It has been demonstrated to have high sensitivity and specificity in discriminating individuals with dysphonia from vocally healthy speakers[41] and good sensitivity in detecting the effects of voice treatment.[42]

***Acoustic Analysis.*** Blinded acoustic analyses using Praat version 6.0.36[43] were performed on patient's deidentified voice samples (44.1 kHz/16-bit, *.wav file format) of the middle 3 seconds of a prolonged /a/, the third CAPE-V sentence[44] "We were away a year ago",[45] and the second and third sentences[46] of the Rainbow Passage.[47] Maximum phonation time (seconds, s) of /a/ was recorded for the longest vowel phonation. Acoustic measures included harmonics-to-noise ratio (HNR) in decibels (dB), fundamental frequency (F0) in hertz (Hz), SD of fundamental frequency (F0SD, Hz), and smoothed cepstral peak prominence (CPPS, dB). Acoustic data was checked by the second author for signal type using criteria described by Sprecher et al.[48] prior to F0 and HNR measurement.

### Statistical Analyses

Data was analyzed using SPSS 22.0[49] (IBM Corp., Armonk, NY) and GraphPad Prism 7.02[50] for Windows (GraphPad Software, Inc., San Diego, CA). Reliability analysis of stroboscopic review was performed by comparing the first and second ratings of AP and lateral constriction. This was done using a percentage of ratings that agreed exactly or within ±1 scale value and the Wilcoxon signed rank test. Related sample tests were used to compare the stroboscopic ratings and acoustic measures before and after the IL procedure. Data was examined for normal distribution using the Kolmogorov–Smirnov test. For normally distributed variables, a paired $t$ test was used, whereas the related-samples Wilcoxon-signed rank test was used for non-normal data. Effect size was calculated in Microsoft Excel 2010

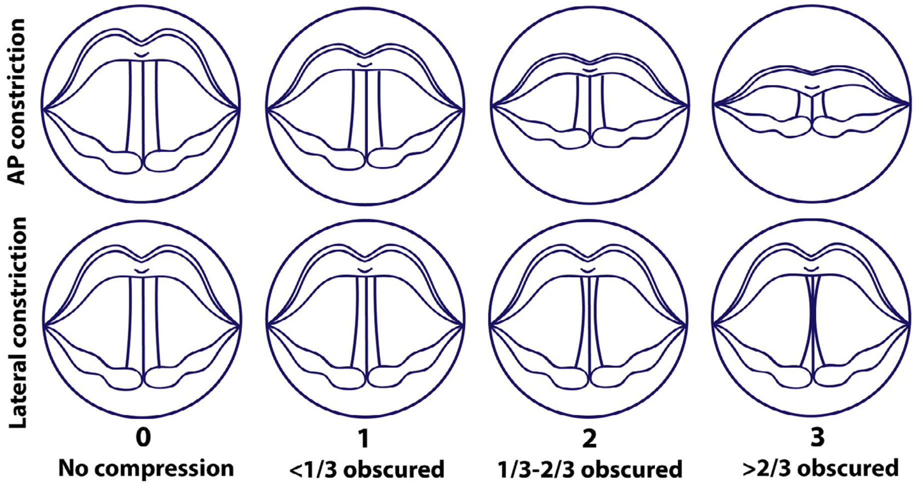


Fig. 2. Stroboscopic ratings of anteroposterior and lateral constriction.

(Microsoft Corp., Redmond, WA) using Cohen's d.[51] Criteria for effect size included "small" (d = 0.2), "medium" (d = 0.5), and "large" (d = 0.8).[51] The significance level was $P < 0.05$.

## RESULTS

### Glottal Insufficiency and Muscle Tension Patterns

Intra-rater reliability of stroboscopic ratings was 91.7% for both AP and lateral constriction. The Wilcoxon signed rank test showed no statistically significant difference in rating scores between the first and second ratings (AP constriction: Z = 0.71, $P = 0.48$; lateral constriction: Z = −1.41, $P = 0.16$).

At baseline, seven of 19 males and 11 of 18 females had stroboscopic evidence of GI based on the above criteria.

Related-samples Wilcoxon signed rank test showed a statistically significant drop in AP constriction score (Z = −2.558, $P = 0.011$, Cohen's d = −0.3) and lateral constriction score (Z = −2.712, $P = 0.007$, Cohen's d = −0.32) after IL compared to baseline.

### VHI-10

Thirty-five patients had both pre- and post-IL VHI-10 data. Thirty (85.7%) showed improvement after IL, with mean (SD) VHI-10 improving from 25.4 (5.7) at baseline to 15.3 (9.3) following IL (t = 7.26, $P < 0.001$, Cohen's d = 0.78). At baseline, there were no differences ($P = 0.893$) in VHI-10 between those with GI (n = 18, mean = 25.5, SD = 6.7) and those without GI (n = 17, mean = 25.2, SD = 4.5). Figure 3 shows that VHI-10 scores decreased after IL for both GI and non-GI patients (for GI: t = 4.978, $P < 0.001$, Cohen's d = 0.77; for non-GI: t = 5.562, $P < 0.001$, Cohen's d = 0.81).

### Acoustic Measures

Table I presents the acoustic voice measures at baseline and 3 months post-IL. Only HNR showed statistically significant improvement after IL (t = −2.785, $P = 0.009$, Cohen's d = 0.47). The effect size was moderate, and the increase in HNR was small. Frequency measures (F0 and F0SD) were lower after IL but not statistically significant. Other measures did not show significant differences following IL.

TABLE I.
Mean (SD) of Voice Measures.

| Acoustic Measures | n | Pre-IL | Post-IL | *P* Value |
|---|---|---|---|---|
| $CPPS_{Vowel}$ (dB) | 29 | 14.2 (4.9) | 14.5 (4.5) | 0.689 |
| $CPPS_{RP}$ (dB) | 29 | 8.4 (2.0) | 8.4 (2.1) | 0.939 |
| $CPPS_{CAPE-V3}$ (dB) | 29 | 10.4 (2.7) | 10.8 (3.3) | 0.483 |
| $F0_{Vowel}$ (Hz) | 29 | 176.9 (66.1) | 165.2 (48.3) | 0.132 |
| F0SD (Hz) | 29 | 4.7 (11.0) | 2.8 (5.4) | 0.155 |
| HNR (dB) | 29 | 21.1 (5.4) | 22.8 (4.3) | 0.009 |
| MPT (s) | 29 | 15.4 (8.6) | 14.3 (7.1) | 0.331 |

CAPE-V3 = Third CAPE-V phrase; CPPS = smoothed cepstral peak prominence; dB = decibel; F0 = fundamental frequency; Hz = hertz; HNR = harmonics-to-noise ratio; IL = injection laryngoplasty; MPT = maximal phonation time; RP = Rainbow Passage; SD = standard deviation.

In 29 patients with available acoustic data, 14 had baseline GI on stroboscopy. Before injection, mean (SD) of HNR in those with and without GI were 20.3 (5.1) dB and 21.9 (5.6) dB, respectively. Only patients with baseline GI showed significant improvement in HNR following IL (t = −3.364, $P = 0.005$, Cohen's d = 0.68) (Fig. 4).

In 29 patients with acoustic data, 16 were male and 13 were female. In males, paired *t* test showed no statistically significant differences after IL in any acoustic measures ($P > 0.05$). In contrast, in females there was improvement in HNR (increased by 2.2 dB after IL, t = −2.297, $P = 0.04$, Cohen's d = 0.55).

### Information About Voice Therapy Following Injection Laryngoplasty

Nineteen patients had information about voice therapy after IL. The remaining participants did not have information regarding whether they underwent voice therapy following the procedure. Therefore, it was impossible to estimate the effects of voice therapy after IL in this study.

## DISCUSSION

In this study, IL was performed in 37 patients with persistent symptomatic MTD after voice therapy as referred by a SLP. IL was offered as a salvage treatment to address

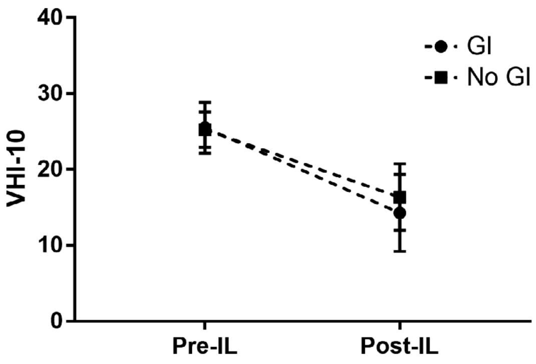


Fig. 3. Changes in VHI-10 (mean and 95% CI) after IL. CI = confidence interval; GI = glottal insufficiency; IL = injection laryngoplasty; VHI = Voice Handicap Index-10.

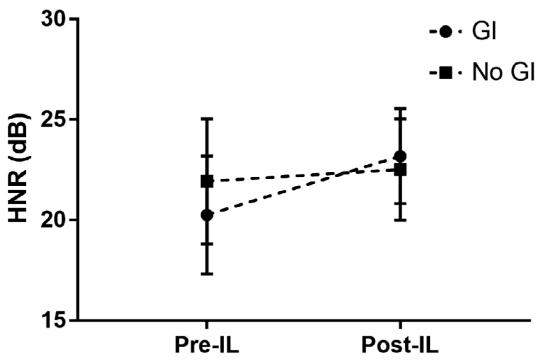


Fig. 4. Changes in HNR (mean and 95% CI) after IL. CI = confidence interval; dB = decibel; GI = glottal insufficiency; HNR = harmonics-to-noise ratio; IL = injection laryngoplasty.

obvious or suspected GI and to help facilitate a better response to voice therapy. The injection materials included cross-linked hyaluronic acid gel, autologous fat, and CaHa. No notable differences between the three types of injection materials were observed in terms of voice symptoms and stroboscopic findings after injection, although numbers in the fat and CaHa groups were small. The study compared pre- and post-IL data of AP and lateral constriction, VHI-10 scores, and acoustic measures. Subgroup comparisons were made as post hoc analyses to evaluate GI and gender as predictive factors on treatment outcome.

This study found a statistically significant decrease in abnormal supraglottal MTPs after IL, implying less phonation effort/compensation after the procedure. This finding was in line with a previous study by Ziade et al.,[37] further supporting the use of this technique in the treatment of MTD following a course of voice therapy. Belafsky et al.[9] suggested that increased MTPs observed endoscopically in MTD may be a sign of excessive compensation for underlying GI. Although it is recognized that MTPs are not specific and fail to discriminate functional dysphonic patients from vocally healthy speakers,[21] they remain useful for assessment of MTD. Additional information including voice quality and patient-reported outcome measures are essential in making the diagnosis and tracking treatment response. The persistence of abnormal MTPs after IL suggests that voice therapy should be maintained following the procedure.

The study also found positive effects of IL on voice-related quality of life, which was independent of baseline GI (Fig. 3). Although the mean post-IL VHI-10 scores remained within the abnormal range,[41] the mean improvement was clinically meaningful[52] and consistent with the response rates and magnitude of change observed in previous studies.[25,29] This suggests that IL assists in more efficient phonation and less muscle effort.

Acoustic voice measures in this study represent various aspects of vocal function, that is, vocal and aerodynamic function (MPT),[53] voicing control (F0 and F0SD) and periodicity, quality, and noise (HNR[54] and CPPS[55]). Of these, only HNR showed improvement following IL in patients with baseline GI (Fig. 4). This may have resulted from more efficient glottal closure after IL and/or more equal tension and mass of the vocal fold (due to the presence of the material bilaterally), thereby increasing periodic vibration and reducing glottal noise in the acoustic signal. The positive effect of injection was not manifested by all acoustic measures such as F0SD and CPPS. Suitable acoustic measures to assess treatment outcomes should be considered in future similar studies.

This study found significant effects of gender on acoustic measures. Acoustic analyses showed that HNR significantly improved in females but not in males. This finding appeared to indicate that IL was more effective in females than males when addressing GI. Differences in anatomical and physiological features between male and female larynges may account for this finding. Vocal fold mass and length are smaller in females than in males; therefore, the effects of the injected volume may be more pronounced. Future studies should aim to quantify the size of the glottal closure in both genders and correlate it with injected volume and other laryngeal biomechanical measures to help identify whether gender predicts benefit from IL.

Data on post-IL voice therapy was not complete for all patients following the procedure. Therefore, it precludes any conclusion regarding the effects of voice therapy after IL. Future research should collect more detailed data related to voice therapy (e.g., number of sessions, duration, techniques, compliance) to clarify the effects of this treatment following IL.

We recognize that stroboscopic assessment of glottal insufficiency is subjective, with a variation in normal ranges and no widely accepted normal values.[56] In this study, a cutoff of <1/3 closed phase of the glottal cycle was used. Objective measures of closure such as kymography or electroglottography may be more accurate in assessing GI. The beneficial effects of IL on patients with GI likely results from improved glottal closure, which led to more efficient phonation requiring less compensatory effort to achieve closure. In those without obvious GI on baseline stroboscopy, we speculate that—although symptomatic—the increased muscle tension may have been adequately compensating for GI and presenting normal stroboscopic findings. Alternatively, the injected volume may have modified vocal pitch by the addition of mass and alterations to dimensions of the vocal folds,[57] thereby changing vocal pitch self-perception[58] and leading to an adjustment of motor control over the laryngeal muscles as a result of altered auditory feedback.[59] This could lead to more efficient and stable use of the laryngeal musculature. This was partly reflected by the lower F0 and F0SD values following IL, although these differences were not statistically significant. Replicating the study in a larger population may help confirm this.

Finally, it is also possible that IL may alter the well-established loop of sensory feedback in MTD at the mechanoceptor level by modifying glottal closure patterns. A previous study has also found evidence for the use of topical anesthesia in MTD,[19] likely exerting similar effects of changed afferent sensory information on laryngeal motor control. Further investigation of sensorimotor pathways in MTD is needed to clarify these assumptions.

## CONCLUSION

This study found that IL improved voice-related quality of life in MTD patients with and without obvious stroboscopic evidence of GI. Both AP and lateral constriction showed significant improvement following IL. The procedure increased HNR in patients with GI who had a lower baseline value of this measure, and this improvement was exclusive to female patients. These findings suggested that IL may be an effective tool in the treatment of MTD that is not resolved with voice therapy. Persistent MTPs after IL implies that voice therapy should be maintained following this procedure. Findings presented in this study were at baseline and within 3 months after injection. The long-term effects of IL on MTD remain unclear and require future research and follow-up studies.

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