Treatment Outcomes of Bilateral Medialization Thyroplasty for Presbylaryngis

*,[1]Jordan J. Allensworth, †Karla O'Dell, ‡Aaron Ziegler, ‡Linda Bryans, ‡Paul Flint, and ‡Joshua Schindler, *Charleston, South Carolina, †Los Angeles, California, and ‡Portland, Oregon

Summary: Background. Presbylaryngis is a common cause of dysphonia in elderly patients. Type I thyroplasty serves to improve glottic closure and vocal quality by correcting bowing. Although unilateral and injection-based procedures are well-characterized in the treatment of broadly defined glottic insufficiency, there are insufficient outcomes data for bilateral medialization thyroplasty in the treatment of presbylaryngis. The aim of this study was to review the change in measures of vocal quality before and after bilateral medialization thyroplasty for presbylaryngis.

Study Design. This is a retrospective case series.

Methods. The records of 21 patients with presbylaryngis undergoing bilateral medialization thyroplasty between 2007 and 2014 were reviewed. Implant materials included silastic (n = 17) and hydroxyapatite (n = 4). Preoperative and postoperative comparison of vocal function was conducted using Voice Handicap Index, maximum phonation time, auditory-perceptual severity ratings, and blinded paired-comparison of Consensus Auditory-Perceptual Evaluation of Voice and Visual-perceptual stroboscopic ratings. Paired sample *t* tests were used to assess all outcome measures.

Results. Significant improvements were found in Voice Handicap Index scores ($P < 0.007$), maximum phonation time ($P < 0.03$), Consensus Auditory-Perceptual Evaluation of Voice ($P < 0.04$), and clinician rating of vocal quality ($P < 0.0001$). Blinded raters noted a significant improvement in audio ($P < 0.05$) and videostroboscopic ($P < 0.003$) samples after surgery. There were no operative complications observed, and median hospital stay was one night.

Conclusions. Patients with presbylaryngis demonstrated significant improvement in both objective and subjective measures of vocal quality following bilateral medialization thyroplasty. These data suggest that medialization thyroplasty is a safe option that warrants consideration in the treatment of presbylaryngis.

Key Words: Presbylaryngis–Atrophy–Medialization–Thyroplasty–Bilateral.

INTRODUCTION

Presbylaryngis is an age-related clinical entity characterized by vocal fold atrophy and bowing that results in glottic incompetence during phonation.[1] Such structural changes produce a constellation of auditory-perceptual voice changes including breathiness, roughness, decreased loudness, pitch change, and increased vocal strain.[2,3] Older adults with voice disorders demonstrate adversely affected quality of life compared with those without voice disorders on the Voice-Related Quality of Life instrument.[4] Presbylaryngis is the most common cause of dysphonia in the elderly, causing up to 30% of cases with a male predominance.[4,5] Recent epidemiologic studies report a 29% prevalence of dysphonia in the general population over the age of 65, with lifetime prevalence as high as 47%.[4] According to projections from the latest US census, the elderly population in the United States is estimated to double by the year 2030, while the number of working elderly persons is projected to increase by 38% by 2020.[6,7] As such, presbylaryngis places a significant functional burden on elderly persons in need of communication to meet workplace demands.

Although presbylaryngis is often treated successfully with voice therapy,[8] refractory disease may be treated with augmentation of the paraglottic space using type I medialization thyroplasty.[9] This surgical procedure aims to improve phonatory closure by correcting for the loss of muscle tissue and lamina propria within the aging vocal folds. Although outcomes of unilateral framework and injection-based medialization have been well documented, outcomes of bilateral type I medialization thyroplasty are limited.[10–12] The aforementioned studies are limited by pooled data from all causes of glottic insufficiency, including paresis, paralysis, and atrophy.[13,14] As such, the outcomes of type I medialization thyroplasty, unilateral or bilateral, have not been investigated for presbylaryngis independent of other causes of glottic insufficiency despite the high prevalence and substantial psychosocial impact of this debilitating vocal condition.[15]

Using a descriptive case series design, the purpose of this study was to assess clinical outcomes of bilateral medialization thyroplasty in the treatment of patients with presbylaryngis. The study was conducted with adherence to the Strengthening the Reporting of Observational Studies in Epidemiology Statement criteria for descriptive studies.[16] The primary outcome variables included change scores for the Voice Handicap Index (VHI), maximum phonation time (MPT), physician auditory-perceptual assessment of vocal impairment before and after bilateral medialization thyroplasty, and blinded auditory-perceptual ratings of vocal impairment and blinded

Accepted for publication October 18, 2017.

All work was performed at Oregon Health & Science University, Department of Otolaryngology-Head and Neck Surgery, 3181 SW Sam Jackson Park Blvd, Portland, OR, USA.

Preliminary data were presented at the Fall Voice Conference from October 15–17, 2015, Pittsburgh, PA, USA.

From the *Department of Otolaryngology-Head & Neck Surgery, Medical University of South Carolina, Charleston, South Carolina; †Department of Otolaryngology-Head and Neck Surgery, Keck School of Medicine, University of Southern California, Los Angeles, California; and the ‡Department of Otolaryngology-Head & Neck Surgery, Oregon Health & Science University, Portland, Oregon.

[1]Present address: MUSC Department of Otolaryngology—Head and Neck Surgery, 135 Rutledge Ave, Charleston SC 29425.

Address correspondence and reprint requests to Jordan Allensworth, MUSC Department of Otolaryngology—Head and Neck Surgery, 135 Rutledge Ave, Charleston SC 29425. E-mail: allenswo@musc.edu

Journal of Voice, Vol. 33, No. 1, pp. 40–44

0892-1997

https://doi.org/10.1016/j.jvoice.2017.10.014

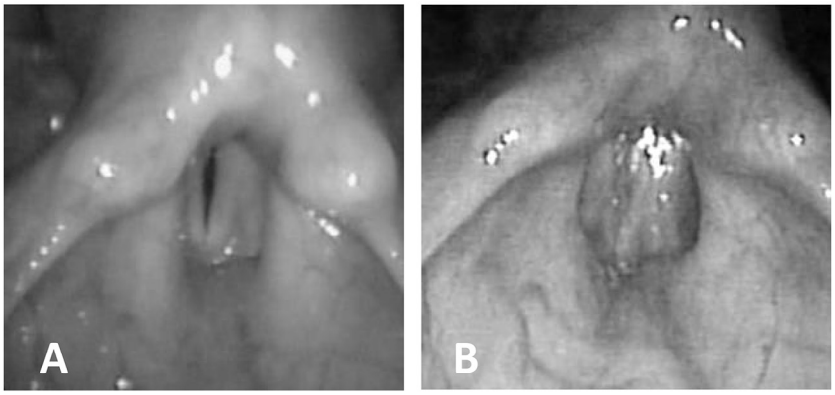

FIGURE 1. **A.** Preoperative example of vocal fold bowing glottic gap. **B.** Postoperative example of complete glottic closure with phonation.

visual-perceptual ratings of vocal fold motion impairment by a voice-specialized speech-language pathologist (SLP).[17] As a secondary outcome variable, the safety of bilateral type I medialization was examined by noting peri- and postoperative complications including airway compromise, bleeding, dysphagia, and adverse events during hospitalization. Although exploratory in nature, we hypothesized that all outcome variables measured would be improved significantly following framework surgery.

MATERIALS AND METHODS

Participants

For this case series, electronic medical records of all patients with a diagnosis of presbylaryngis treated with bilateral medialization thyroplasty at Oregon Health & Science University between 2007 and 2015 were compiled following institutional review board approval. Patients with any neurologic or anatomic condition other than presbylaryngis that could lead to dysphonia or vocal fold motion impairment were excluded.

Procedures

All participants underwent comprehensive, multidisciplinary voice evaluation with a board-certified otolaryngologist and voice-specialized SLP to derive the diagnosis of presbylaryngis.[18] Assessment procedures included videolaryngostroboscopic imaging using an Olympus distal chip flexible endoscope (Olympus Medical, Center Valley, PA) to evaluate vocal fold appearance, wave characteristics, and closure description. An unblinded auditory-perceptual evaluation of voice was conducted by a board-certified laryngologist using an adaption of the Hirano scale consisting of 0 (*normal voice* [ie, no dysphonia]), 1 (*mild dysphonia*), 2 (*moderate dysphonia*), and 3 (*severe dysphonia*).[19] In addition, a blinded auditory-perceptual evaluation of voice was completed by an SLP using the Consensus Auditory-Perceptual Evaluation of Voice.[20] Finally, acoustic testing was performed using the KayPentax Computerized Speech Laboratory Model 4150B (Pentax Medical, Montvale, NJ) and a Shure SM48 handheld dynamic cardiod microphone (Shure Incorporated, Niles, IL) maintained at 30 cm from the patient's mouth. Importantly, stimulability testing with trial voice therapy was completed to determine the most appropriate treatment approach. Medialization materials included carved silastic implants (Netterville, Medtronic Xomed, Inc, Jacksonville, FL) in 17 patients and preformed hydroxyapatite (VoCoM, Gyrus ACMI, Southborough, MA) in four patients.

Data were collected from electronic medical records for the eligible patients including demographic information, medical comorbidities, number of voice therapy sessions attended, operative course, VHI scores, and MPT from digital voice recordings. For MPT before and after surgery, patients were instructed to take a full breath and sustain /a/ at a typical speaking pitch and loudness for as long as possible. The total duration of time between the start and end of the acoustic signal was calculated from the patient's medical record. Auditory-perceptual data based on unblinded physician assessment of voice quality were retrieved from the patient's medical record before and after surgery. Three voice-specialized SLPs prospectively rated the overall severity of dysphonia of previously recorded pre- and postoperative digital voice samples using a paired-comparison paradigm.[21] In this paradigm, reviewers compared before and after samples for each patient and were blinded to which sample was preoperative or postoperative, respectively. For the auditory-perceptual rating task, SLPs blinded to pre- versus postoperative status with sound-isolating headphones were presented with randomly ordered sets of digital audio recordings that included 5 seconds of sustained /a/ and the first three sentences of the Rainbow Passage.[22] Severity was judged by placing a mark along a 100-mm visual analog scale, with 0 representing "No voice problem at all," and 100 representing "Most severe voice problem." The same rating system was used for blinded visual-perceptual ratings of overall vocal fold vibratory behavior and glottic closure (Figure 1). Pre- and postoperative audiovisual samples consisted of 5 seconds of sustained /a/ and rote counting from 1 to 10. Randomization of all samples was accomplished using web-based randomization software.[23]

Statistical analysis was performed to determine whether each variable examined demonstrated postoperative differences using paired (dependent) *t* test of intra-subject change in each variable following medialization with a significance level of $P \leq 0.05$. Means and standard deviations were calculated for each study variable. Only complete pre- and postoperative data sets for each variable were used, with all partial data sets removed from analysis.

RESULTS

Thirty patients were identified for this clinical outcomes study upon review of medical charts. Five patients were excluded due to a concurrent diagnosis of Parkinson disease, two patients due to prior cerebrovascular accident with neurologic dysphonia and dysarthria, and two patients due to a history of unilateral vocal fold paralysis. Thus, a total of 21 patients who underwent bilateral medialization thyroplasty for presbylaryngis met the criteria for inclusion. The mean age of participants was 76 years old; the group consisted of 17 males (81%). Prior to medialization, 12 patients (57%) underwent a mean of 3.1 voice therapy sessions. Following surgery, 16 patients (76%) attended a mean of 5.5 voice therapy sessions. Nine patients (43%) had undergone injection medialization prior to medialization thyroplasty, all with Cymetra injections administered an average of 8.9 months prior to surgery. Videolaryngostroboscopy was performed an average of 31.0 ± 40.4 days preoperatively and 49 ± 79.3 days following medialization surgery. Additional participant characteristics are summarized in Table 1.

The number of participants with data for each measure is listed in Table 2. Ninety percent of patients (9/10) with complete sets of pre- and postoperative VHI scores exhibited an improvement in vocal handicap. The mean preoperative VHI score was 59.4 (*SD* = 15.5) and the mean postoperative VHI score was 31.5 (*SD* = 18.7), indicating a statistically significant reduction in voice handicap ($P < 0.007$) (Table 2). Similarly, a perceived improvement in voicing and glottic closure was found in 100% (17/17) of those assessed by the physician before and after medialization. The mean pre- and postoperative auditory-perceptual severity as rated by the laryngologist was 2.5 (*SD* = 0.6) and 1.3 (*SD* = 0.3), respectively, which was statistically significant ($P < 0.0001$).

MPT was increased after surgery in 85% (11/13) of patients with complete sets of measurements. The preoperative mean was 10.4 seconds (*SD* = 6.1) and the postoperative mean was 14.3 seconds (*SD* = 7.1). This pre- to postoperative increase in MPT was statistically significant ($P < 0.03$).

Auditory-perceptual severity of voice as determined by a composite score of ratings by three blinded SLPs improved pre- to postoperatively for 88% of patients (7/8). The mean preoperative score was 38 (*SD* = 20.7) and the mean postoperative score was 20.6 (*SD* = 7.2), a statistically significant improvement ($P < 0.05$). Blinded scoring of sets of stroboscopic samples decreased from a preoperative mean of 40.3 (*SD* = 6.2) to 25.2 (*SD* = 11.9) postoperatively. This improvement captured 88% of patients (7/8) and achieved statistical significance ($P < 0.003$).

For all outcome measures, an independent samples *t* test analysis was performed, with statistical significance seen for VHI ($P = 0.001$), Consensus Auditory-Perceptual Evaluation of Voice ($P = 0.04$), visual-perceptual stroboscopic ratings ($P = 0.006$), and perceptual severity rating ($P = 0.0001$). Independent samples *t* test was not statistically significant for MPT ($P = 0.16$).

The mean length of hospital stay was 1 day, with a range of 0–2 days. Of the 21 patients who underwent bilateral medialization in this study, none experienced airway complications or required surgical revision. No participants in the study experienced dysphagia, excessive bleeding requiring intervention, or adverse events as a result of hospitalization.

TABLE 1.
Participant Characteristics

Patient Characteristics	N	%
Total	21	
Mean age (y)	76	
Male	17	81
Female	4	19
Prior voice therapy	12	57
Number of sessions (M, SD)	3.1 ± 1.8	
Prior injection medialization	9	43
Postoperative voice therapy	16	76
Number of sessions (M, SD)	5.5 ± 3.9	
GERD	7	33
COPD	3	14
Diabetes mellitus type 2	3	14
CAD	3	14
Asthma	2	9

Abbreviations: GERD, gastroesophageal reflux disease; COPD, chronic obstructive pulmonary disease; CAD, coronary artery disease.

DISCUSSION

This case series aimed to evaluate clinical outcomes of bilateral medialization thyroplasty on validated measures including the VHI, MPT, and perceptual assessment of vocal impairment.[24]

TABLE 2.
Pre- and Postoperative Outcome Data

Outcome Variable	N	Mean ± SD		*P* Value
		Preoperative	Postoperative	
VHI	10	59.4 ± 15.5	31.5 ± 18.7	0.0068*
MPT (s)	13	10.4 ± 6.1	14.3 ± 7.1	0.0242*
CAPE-V	8	38.0 ± 20.7	20.6 ± 7.2	0.0441*
Visual-perceptual stroboscopic ratings	8	40.3 ± 6.2	25.2 ± 11.9	0.0027*
Perceptual severity rating	17	3.3 ± .3	2.3 ± .3	<0.0001*

Abbreviations: VHI, Voice Handicap Index; MPT, maximum phonation time; CAPE-V, Consensus Auditory-Perceptual Evaluation of Voice.
* Statistically significant.

As hypothesized, framework surgery was shown to be effective in the treatment of refractory presbylaryngis for the cohort examined.

Ninety percent of patients registered a reduction in VHI, a validated assessment of vocal health. As reported previously, lack of improvement in VHI may be attributable to unrealistic expectations of surgical intervention, coinciding memory loss, or concurrent neurologic dysphonia and persistent mismatches in the volume of the paraglottic space and continued hoarseness despite improved glottic closure and MPT.[25] In addition, recent findings suggest nearly 61% of presbyphonia patients exhibit a respiratory impairment based on abnormal spirometric values that may contribute to persistent vocal impairment despite improved glottal competence.[25] For patients with ongoing vocal handicap after medialization, exuberant voice therapy in which greater pulmonary drive is demanded from the patient may be a useful postoperative treatment to manage existing respiratory deficits that are unaddressed with framework surgery.[8]

Our findings of improved VHI strengthen and complement previous findings. In the only extant implant-based study, Postma et al reported 94% of patients (n = 16) displayed improved quality of life following bilateral framework surgery using a custom questionnaire.[13] All six patients with presbylaryngis who underwent bilateral medialization in a report by Netterville and colleagues (1993) demonstrated a subjective improvement in voicing and swallowing, although objective data and VHI scores specific to those patients were not collected.[14] As noted, nine study participants had previously undergone injection laryngoplasty using Cymetra for a mean duration of 8.9 months before thyroplasty, at which time the clinical effect of remnant injection material is expected to have dissipated.[26] The specific effect of remnant injection material was not addressed in this study.

We found significant increases following medialization thyroplasty in MPT, a measure of vocal quality with high intrarater reliability.[27,28] Specifically, MPT has been correlated to laryngeal airway resistance and increases as the rate of airflow across the glottis decreases.[29] Supporting this assertion is a series of patients undergoing unilateral injection medialization with calcium hydroxylapatite, in which Rosen and Thekdi (2004) found that medialization was associated with a decreased mean phonatory airflow rate.[30] Our findings suggest that framework surgery significantly improves laryngeal airflow resistance by restoring glottic competence in subjects with presbylaryngis, thereby impacting MPT. Lu and colleagues (1998) compared selected acoustic measures following medialization in patients with nonparalytic glottic incompetence to those with true vocal fold paralysis. However, only 5 of 17 participants (29%) met criteria for presbylaryngis, and it is not reported whether any underwent bilateral medialization.[31]

Videostroboscopic samples, central to the diagnosis of presbylaryngis,[1] were randomized and presented to blinded raters in a paired-comparison format to reduce potential rater and patient biases. Ratings by SLPs using standardized audio and stroboscopic samples indicated significantly reduced severity of dysphonia and improvement in glottis closure. These ratings provide a novel method of assessing outcomes of medialization thyroplasty, for which a consensus approach has been notably evasive.[24]

The absence of complications in this report is consistent with previous descriptions of bilateral type I thyroplasty.[13,14,24] Existing evidence suggests that bilateral type I medialization with materials such as silastic has an acceptable safety profile and does not pose a significantly elevated airway risk.[32] In fact, this procedure may increase overall safety for patients with glottic incompetence by decreasing the risk of aspiration.[33] In one study of 112 patients by Bowen et al, the complication rate and outcomes for patients over age 65 were found to be similar to younger patients, further supporting the role of thyroplasty as a safe option in the treatment of presbylaryngis.

The role of voice therapy in predicting outcomes of type I thyroplasty is unknown, and existing data are limited to a total of six patients.[24] Voice therapy is often employed as a first-line therapy for patients with presbylaryngis and has proven effective using VHI scores, blinded audio comparisons, and acoustic and aerodynamic measures.[8,34,35] In this investigation, 57% of patients had undergone prior voice therapy prior to thyroplasty. The most common documented reason for cessation of voice therapy was lack of patient perceived improvement. Similar to the larger cohort, 86% (5/6) of these patients showed improved VHI following medialization. Larger sample sizes are necessary to determine if a statistically significant relationship exists between preoperative voice therapy and medialization success.

Limitations to this study include limited sample size and variable quantities of data available for each of the measures examined. Although efforts were made to obtain responses and records for all participants, data collected at perioperative visits were variable among the cohort presented. As a result, the number of patients available for each variable ranged from 8 to 17, or 38%–80% of the total cohort of patients. Given the sample sizes for each outcome variable, an independent samples *t* test was performed to determine the level of bias present, revealing statistical significance in all variables except MPT. These findings support that deficits in outcome values were due to variable collection practices rather than lack of follow-up or patient characteristics. Acoustic measures in particular may require larger sample sizes to confirm unbiased significance.

Existing publications addressing bilateral medialization for presbylaryngis consist only of case reports and smaller patient totals than that presented in this study for any given outcome measure. Furthermore, existing data are lumped into larger cohorts of all-cause dysphonia, making presbylaryngis-specific data indecipherable.[12,36] Extant studies are noted to include pooled unilateral and bilateral medialization outcomes without the possibility of extracting information for a single procedure. This study aimed to explore the outcomes of treatment of a single condition, presbylaryngis, with a single procedure, bilateral type I medialization thyroplasty. Future research should prospectively study a cohort of patients who undergo bilateral medialization thyroplasty with age- and sex-matched controls.

CONCLUSION

Presbylaryngis is a common and often debilitating condition for which precise treatment outcomes remain unknown. A need exists

for standardized reporting of outcomes of presbylaryngis treatment, including results specific to medialization thyroplasty. In this investigation, we examined the outcomes of bilateral framework surgery specific to patients diagnosed with presbylaryngis. In this observational study, we found significant improvement in all outcome measures without notable complications, further supporting the need for characterization of type I thyroplasty as a treatment option for presbylaryngis.

FUNDING

This study was funded by OHSU's Department of Otolaryngology-Head and Neck Surgery.

REFERENCES

1. Bloch I, Behrman A. Quantitative analysis of videostroboscopic images in presbylarynges. *Laryngoscope*. 2001;111(11 pt 1):2022–2027.
2. von Leden H, Alessi D. *The Aging Voice*. New York, NY: Thieme Medical Publishers; 1994.
3. Ramig LO, Gray S, Baker K, et al. The aging voice: a review, treatment data and familial and genetic perspectives. *Folia Phoniatr Logop*. 2001;53:252–265.
4. Roy N, Stemple J, Merrill RM, et al. Epidemiology of voice disorders in the elderly: preliminary findings. *Laryngoscope*. 2007;117:628–633.
5. Reulbach TR, Belafsky PC, Blalock PD, et al. Occult laryngeal pathology in a community-based cohort. *Otolaryngol Head Neck Surg*. 2001;124:448–450.
6. Vincent G, Velkoff V. The next four decades: the older population in the United States: 2010 to 2050. *Curr Popul Rep*. 2013;1–14.
7. Toossi M. Labor force projections to 2020: a more slowly growing workforce. *Monthly Lab. Rev.* 2012;135:43.
8. Ziegler A, Verdolini Abbott K, Johns M, et al. Preliminary data on two voice therapy interventions in the treatment of presbyphonia. *Laryngoscope*. 2014;124:1869–1876.
9. Isshiki N, Morita H, Okamura H, et al. Thyroplasty as a new phonosurgical technique. *Acta Otolaryngol*. 1974;78:451–457.
10. Elnashar I, El-Anwar M, Amer H, et al. Voice outcome after Gore-Tex medialization thyroplasty. *Int Arch Otorhinolaryngol*. 2015;19:248–254.
11. Kwon TK, An SY, Ahn JC, et al. Calcium hydroxylapatite injection laryngoplasty for the treatment of presbylaryngis: long-term results. *Laryngoscope*. 2010;120:326–329.
12. Salinas JB, Chhetri DK. Injection laryngoplasty: techniques and choices of fillers. *Curr Otorhinolaryngol Rep*. 2014;2:131–136.
13. Postma GN, Blalock PD, Koufman JA. Bilateral medialization laryngoplasty. *Laryngoscope*. 1998;108:1429–1434.
14. Netterville JL, Stone RE, Luken ES, et al. Silastic medialization and arytenoid adduction: the Vanderbilt experience. A review of 116 phonosurgical procedures. *Ann Otol Rhinol Laryngol*. 1993;102:413–424.
15. Turley R, Cohen S. Impact of voice and swallowing problems in the elderly. *Otolaryngol Head Neck Surg*. 2009;140:33–36.
16. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies. *Int J Surg*. 2014;12:1495–1499.
17. Jacobson B, Johnson A, Grywalski C, et al. Voice Handicap Index: development and validation. *Am J Speech Lang Pathol*. 1997;6:66–70.
18. Bradley JP, Johns MM III. The aging voice. In: Sataloff RT, Benninger MS, eds. *Sataloff's Comprehensive Textbook of Otolaryngology: Head & Neck Surgery: Laryngology*. Philadelphia: JP Medical Publishers Ltd; 2015:635–640.
19. Hirano M. Objective evaluation of the human voice: clinical aspects. *Folia Phoniatr (Basel)*. 1989;41:89–144.
20. Kempster GB, Gerratt BR, Verdolini Abbott K, et al. Consensus auditory-perceptual evaluation of voice: development of a standardized clinical protocol. *Am J Speech Lang Pathol*. 2009;18:124–132.
21. Kreiman J, Gerratt BR, Ito M. When and why listeners disagree in voice quality assessment tasks. *J Acoust Soc Am*. 2007;122:2354–2364.
22. Fairbanks G. *Voice and Articulation Drillbook*. 2nd ed. Harper & Row; 1960.
23. Available at: Randomizer.org. Accessed June 15, 2015.
24. Shen T, Damrose EJ, Morzaria S. A meta-analysis of voice outcome comparing calcium hydroxylapatite injection laryngoplasty to silicone thyroplasty. *Otolaryngol Head Neck Surg*. 2013;148:197–208.
25. Vaca M, Mora E Cobeta I. The aging voice: influence of respiratory and laryngeal changes. *Otolaryngol Head Neck Surg*. 2015;153:409–413.
26. Mallur PS, Rosen CA. Vocal fold injection: review of indications, techniques, and materials for augmentation. *Clin Exp Otorhinolaryngol*. 2010;3:177–182.
27. Speyer R, Bogaardt HC, Passos VL, et al. Maximum phonation time: variability and reliability. *J Voice*. 2010;24:281–284.
28. Eckel FC, Boone DR. The S/Z ratio as an indicator of laryngeal pathology. *J Speech Hear Disord*. 1981;46:147–149.
29. Solomon NP, Garlitz SJ, Milbrath RL. Respiratory and laryngeal contributions to maximum phonation duration. *J Voice*. 2000;14:331–340.
30. Rosen CA, Thekdi AA. Vocal fold augmentation with injectable calcium hydroxylapatite: short-term results. *J Voice*. 2004;18:387–391.
31. Lu FL, Casiano RR, Lundy DS, et al. Vocal evaluation of thyroplasty type I in the treatment of nonparalytic glottic incompetence. *Ann Otol Rhinol Laryngol*. 1998;107:113–119.
32. Bray D, Young JP, Harries ML. Complications after type one thyroplasty: is day-case surgery feasible? *J Laryngol Otol*. 2008;122:715–718.
33. Thevasagayam MS, Willson K, Jennings C, et al. Bilateral medialization thyroplasty: an effective approach to severe, chronic aspiration. *J Laryngol Otol*. 2006;120:698–701.
34. Sauder C, Roy N, Tanner K, et al. Vocal function exercises for presbylaryngis: a multidimensional assessment of treatment outcomes. *Ann Otol Rhinol Laryngol*. 2010;119:460–467.
35. Gorman S, Weinrich B, Lee L, et al. Aerodynamic changes as a result of vocal function exercises in elderly men. *Laryngoscope*. 2008;118:1900–1903.
36. Shah RN, Deal AM, Buckmire RA. Multidimensional voice outcomes after type I Gore-Tex thyroplasty in patients with nonparalytic glottic incompetence: a subgroup analysis. *Laryngoscope*. 2013;123:1742–1745.