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# Vocal Fold Bowing in Elderly Male Monozygotic Twins: A Case Study

Kristine Tanner  
*The University Of Utah*

Cara Sauder  
*University of Utah Hospitals and Clinics*

*See next page for additional authors*

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**Authors**

Kristine Tanner, Cara Sauder, Susan L. Thibeault, Christopher Dromey, and Marshall E. Smith

1                   Vocal Fold Bowing in Elderly Male Monozygotic Twins: A Case Study

2  
3  
4                   Kristine Tanner, Ph.D.  
5                   Department of Communication Sciences & Disorders and  
6                   Division of Otolaryngology—Head & Neck Surgery  
7                   The University of Utah  
8                   390 S. 1530 E., rm. 1310 BEH SCI  
9                   Salt Lake City, UT 84112-0252  
10                  kristine.tanner@hsc.utah.edu  
11                  (801) 633-7471  
12                  (801) 581-7955 (fax)

13  
14                  Cara Sauder, MA  
15                  Voice Disorders Center, University of Utah Hospitals and Clinics  
16                  Division of Otolaryngology-Head & Neck Surgery  
17                  Surgical Specialty Center  
18                  CAMT Building  
19                  729 Arapeen Dr.  
20                  Salt Lake City, UT 84108  
21                  cara.sauder@hsc.utah.edu  
22                  (801) 585-7946  
23                  (801) 587-3569 (fax)

24  
25                  Susan L. Thibeault, Ph.D.  
26                  Division of Otolaryngology—Head & Neck Surgery  
27                  The University of Wisconsin—Madison  
28                  5107 Wisconsin Institute of Medical Research  
29                  1111 Highland Ave  
30                  Madison, Wisconsin 53705-2275  
31                  thibeault@surgery.wisc.edu  
32                  (608) 263-6751  
33                  (608) 263-6199 (fax)

34  
35                  Christopher Dromey, Ph.D.  
36                  Communication Disorders  
37                  Brigham Young University  
38                  133 TLRB  
39                  Provo, UT 84602  
40                  dromey@byu.edu  
41                  (801) 422-6461

42  
43                  Marshall E. Smith, MD  
44                  Division of Otolaryngology—Head & Neck Surgery  
45                  The University of Utah and  
46                  Primary Children's Medical Center

50 N. Medical Drive  
3C 120 SOM  
Salt Lake City, UT 84132  
(801) 588-2782  
(801) 587-3569 (fax)

A portion of this study was presented at the Voice Foundation Annual Symposium,  
Philadelphia, PA, June 4, 2006.

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1 Abstract

2 *Objectives:* This study examined case histories, diagnostic features, and treatment  
3 response in two 79-year-old male monozygotic (identical) twins with vocal fold bowing,  
4 exploring both genetic and environmental factors.

5 *Study Design:* Case study.

6 *Methods:* DNA concordance was examined via cheek swab. Case histories,  
7 videostroboscopy, auditory- and visual-perceptual assessment, electromyography,  
8 acoustic measures, and Voice Handicap ratings were undertaken. Both twins underwent  
9 surgical intervention and subsequent voice therapy.

10 *Results:* Monozygosity was confirmed for DNA polymorphisms, with 10 of 10  
11 concordance for STR DNA markers. For both twins, auditory and visual-perceptual  
12 assessments indicated severe bowing, hoarseness and breathiness, although Twin 1 was  
13 judged to be extremely severe. Differences in RMS amplitudes were observed for TA and  
14 LCA muscles, with smaller relative amplitudes observed for the Twin 1 versus Twin 2.  
15 No consistent voice improvement was observed following surgical intervention(s),  
16 despite improved mid-membranous vocal fold closure. Marked reductions in Voice  
17 Handicap Index total scores were observed following behavioral voice therapy,  
18 coinciding with increased mid-membranous and posterior laryngeal (interarytenoid)  
19 glottal closure. No substantive differences in acoustic measures were observed.

20 *Conclusions:* Vocal fold bowing was more severe for Twin 1 versus Twin 2 despite  
21 identical heritability factors. Overall voice improvement with treatment was greater for  
22 Twin 2 than Twin 1. Environmental factors might partially account for the differences  
23 observed between the twins, including variability in their responsiveness to behavioral

1 voice therapy. Voice therapy was useful in improving mid-membranous and posterior  
2 laryngeal closure, although dysphonia remained severe in both cases.

3 **KEYWORDS:** twins, bowing, EMG, breathiness, aging

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## Introduction

Presbylaryngis, or aging of the larynx, is a relatively common diagnosis in the elderly and is characterized by the laryngeal appearance of vocal fold bowing and dysphonia.<sup>1</sup> Incidence rates of bowing are as high as 30% in elderly clinical (treatment-seeking) populations,<sup>2,3</sup> and disagreement exists regarding whether vocal fold bowing is a normal part of the aging process or should be considered pathological.<sup>4</sup> Age-related changes in laryngeal structures and function are well-documented, although to what extent these might contribute to dysphonia and/or bowing is unclear.<sup>5</sup> The precise etiology of vocal fold bowing, including its progression, treatment responsiveness, and the relative contribution of genetic and environmental factors, remains unknown. Some evidence exists of both genetic and environmental influences on aspects of voice disorders and vocal aging, including auditory-perceptual features and disorder types, although no studies have specifically examined the relationship between these factors and vocal fold bowing. Recent twin studies have more closely examined the interaction between environmental factors, such as occupational voice demands, and genetics in dysphonia.<sup>6</sup> This case study provides a unique opportunity to explore the history, clinical presentation, and treatment response in two male geriatric monozygotic twins with vocal fold bowing.

Research suggests that neuromuscular, histological, and musculoskeletal changes occur with advanced chronological age, and bowing in the elderly population is presumed to reflect atrophic changes of the thyroarytenoid (TA) muscle. Although not specific to idiopathic vocal fold bowing, electromyography (EMG) research has compared TA motor unit durations, relative, average and absolute motor unit amplitudes in younger and

1 older individuals, as well as those with Parkinson's Disease.<sup>7</sup> The results indicated that  
2 elderly speakers produced higher mean amplitudes than the younger group and lower  
3 mean amplitudes compared to the PD group. Maximum TA absolute values were highest  
4 in the elderly group, resulting in lower relative amplitudes compared to both the younger  
5 group and the PD group. Consistent with these findings of higher mean and maximum  
6 TA amplitudes, motor unit durations were also increased in elderly males compared to  
7 younger participants.<sup>8</sup> Collectively, EMG findings of increased motor unit amplitudes  
8 and durations presumably represent activation of denervated/reinnervated muscle fibers  
9 and greater motor unit recruitment. EMG findings corroborate histological findings of  
10 muscle fiber reorganization and composition alteration with age. An age-related  
11 reduction in length of type 1 slow twitch muscle fibers and greater numbers of co-  
12 localized fibers also support evidence of motor unit remodeling following cycles of  
13 denervation and reinnervation.<sup>9</sup>

14       Extra-cellular matrix (ECM) composition of the lamina propria is an important  
15 determinant of the viscoelastic properties of the vocal folds that are required for  
16 phonation. Histological analysis has revealed age-related changes in ECM components  
17 such as collagenous and reticular fibers, protein distributions, and hyaluronic acid (HA)  
18 levels.<sup>10</sup> An age-related reduction in interstitial space in the superior lamina propria as  
19 well as degradation and reduction in reticular fibers, which allow for greater tissue  
20 compliance compared to collagenous fibers, has also been observed.<sup>11</sup> These alterations  
21 impact elastic properties and might explain the characteristic glottal incompetence and  
22 alteration of vibratory characteristics observed in vocal fold bowing. In addition to  
23 potential changes in elastic properties of the vocal folds, viscosity is also associated with



1 vocal effort, vibratory efficiency, and phonation threshold pressure.<sup>13</sup> Viscosity is  
2 influenced by the relative concentration of HA, which influences water content  
3 regulation. A trend towards less overall HA in the ECM has also been observed in older  
4 as compared to younger individuals.<sup>10</sup> In addition to reductions in HA concentration,  
5 laryngeal gland atrophy in the region of the false folds has also been documented in older  
6 adults.<sup>14</sup> Other signs of drying such as a reduction in secretory granules in serous cells  
7 and mucigen droplets have been reported.<sup>11</sup> There is also evidence that the decline in lung  
8 elasticity and respiratory strength associated with aging might further degrade phonatory  
9 efficiency.<sup>12</sup> Voice changes and their association with increasing chronological age have  
10 been well-documented, however there are often no distinctions within medical and voice-  
11 related histories to determine whether or not these changes are a normal part of the aging  
12 process or are pathological. However, the voice changes associated with increasing  
13 chronological age are compatible with many of the clinical features of vocal fold bowing.

14         Structural and physiological changes have been observed with increasing  
15 chronological age. However, the rate of aging varies such that chronological and  
16 physiological age might differ. Both genetic and environmental factors influence the  
17 aging process and might explain some of the changes observed in the aging voice.  
18 Differences in auditory-perceptual and acoustic voice characteristics of individuals of the  
19 same chronological age indicate some variability in the rate of vocal aging. Ramig and  
20 colleagues<sup>15</sup> studied two- and three-generation families to determine if other  
21 physiological measures of aging were similar to that of vocal aging. Listener-perceived  
22 age and some acoustic data correlated with measures of physiological aging, such as bone  
23 density and loss of visual acuity. Heritability patterns in physiological aging and its

1 relationship with vocal aging has also been observed. Familial similarities in voice  
2 characteristics of monozygotic (MZ) and dizygotic (DZ) twins, as well as higher  
3 prevalence rates of voice disorders in those with a family history of voice disorders  
4 families have been reported.<sup>16</sup> Fairly high correlations between fundamental frequencies  
5 ( $F_0$ ) of MZ and DZ twin pairs have been observed, with a greater correlation in MZ twins  
6 when controlling for height and weight.<sup>17</sup> Similarities in maximum phonation times and  
7 perceptual voice characteristics in MZ twins have also been identified.<sup>18</sup> Interestingly, a  
8 perhaps expected decline in the correlation between  $F_0$  in twin pairs over time as a result  
9 of increased environmental influence has not been observed, suggesting a strong genetic  
10 influence.<sup>19</sup> The precise nature and relative contribution of environmental influences on  
11 vocal aging is unknown. Nevertheless, the role of occupational voice use in predicting  
12 voice disorders and voice complaints has been clearly established.<sup>6, 16</sup> A recent twin study  
13 investigated the effects of genetic and high occupational voice demands in MZ and DZ  
14 twins.<sup>6</sup> Surveys regarding specific voice problems were administered to MZ and DZ twin  
15 pairs with either high or low occupational voice demands. A moderate genetic effect was  
16 observed for the presence of voice problems, but environmental factors such as  
17 occupational voice demands had a greater effect. Although no age effect was observed,  
18 these twin pairs were relatively young (i.e., under 45 years of age).

19         The present investigation was undertaken in order to study in detail the case  
20 histories, diagnostic features, and responses to treatment in two 79-year-old male MZ  
21 twins with vocal fold bowing. A longitudinal, descriptive case study design afforded the  
22 opportunity to examine similarities and differences in the onset, progression, course, and

1 response to treatment exploring both genetic and environmental factors. Auditory- and

2 visual-perceptual, acoustic, and EMG measures were compared.

3

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## Methods

### *Participants*

Two elderly male, monozygotic (identical) twins participated in this study (age = 79 years). Both twins were seen at The Voice Disorders Center at The University of Utah in May of 2005 for assessment and management related to complaints of hoarseness, vocal weakness and dysphagia. The diagnosis of vocal fold bowing was confirmed by a multidisciplinary team including a speech-language pathologist and an otolaryngologist following a detailed case history, auditory-perceptual analysis, and rigid videolaryngostroboscopy. Zygoty determination was undertaken using DNA polymorphisms, and the twins were concordant for 10 out of 10 STR DNA markers, indicating monozygosity with a greater than 99% probability (Affiliated Genetics, Salt Lake City, UT).

### *Case History*

*Environmental history.* The twins were born and reared together, and have lived in close proximity to one another since birth in a rural area in Northern Utah. Both twins worked the majority of their adult lives as carpenters, were married in their mid-twenties, raised children, and never divorced. In their mid-sixties, both twins retired; however, Twin 1 was subsequently widowed (for 10 years prior to his initial evaluation at our clinic) and continued to live alone and work on a cattle ranch. Twin 2 continued to reside with his spouse throughout the duration of the study.

*Medical history.* With respect to the twins' medical histories, Twin 1 reported high cholesterol, high blood pressure, arrhythmia, and a previous of pneumonia. Twin 1's previous surgeries included hernia repair, rotator cuff repair, and a non-specified heart

1 surgery for “irregular heart beat”, presumed to be pacemaker placement. Both twins were  
2 non-drinkers and non-smokers throughout their lifetimes. Medications included  
3 Lisinopril, Crestor, and aspirin. Twin 2’s medical history was unremarkable, with no  
4 health conditions or previous surgeries reported and no medications. However, Twin 2  
5 reported that he experienced frequent acid reflux symptoms.

6 Two-channel 24-hour pH probe with manometry was undertaken, and reflux  
7 occurrences, durations, and levels (i.e., when  $\text{pH} < 4$ ) were recorded for proximal and  
8 distal channels. Twin 1 had a significantly elevated Demeester score and was diagnosed  
9 with pathological gastroesophageal reflux. Twin 2’s pH probe results were unremarkable.

10 *Voice history.* Regarding voice and swallowing complaints, Twin 1 reported a 20  
11 year history of a weak, breathy voice as well as effortful voice production that gradually  
12 worsened in severity. He rated his voice as 50% of normal at the time of his initial  
13 evaluation in May of 2005 (0% = no voice at all; 100% = completely normal voice). He  
14 reported a 10-year history of swallowing difficulties with both solid foods and liquids;  
15 however, he never sought medical attention for dysphagia.

16 Twin 2 reported a five-year history of a weak, hoarse voice. He rated his voice as  
17 50% normal at the time of his initial evaluation. Twin 2 reported a three-year history of  
18 swallowing difficulties with solid foods, and a chin-tuck swallowing maneuver was  
19 recommended following modified barium swallow study performed at that time.  
20 However, speech/dysphagia therapy was not recommended at that time, and Twin 2  
21 reported no improvement with the chin tuck maneuver.

22 *Psychosocial history.* With respect to psychosocial history, Twin 1 reported that  
23 he was fairly quiet and did not interact much with others since his wife died. He spoke

1 with his brother often; however, this was generally the extent of his daily social  
2 interaction. He talked with his children occasionally over the telephone, and also  
3 interacted socially at church on Sundays. Twin 2 reported that he was more talkative than  
4 his twin brother, and spent the majority of his days at home with his wife and in his  
5 carpentry shop. He interacted with his brother and children over the telephone and at  
6 church on Sundays.

### 7 *Initial Voice and Speech Assessment*

8         The results from the twins' comprehensive voice and speech assessment in May  
9 of 2005 revealed severe vocal fold bowing with prominent auditory-perceptual features  
10 of severe breathiness and hoarseness, although Twin 1 demonstrated "extremely severe  
11 dysphonia". Maximum phonation time (MPT) for Twin 1 was one second, and was less  
12 than two seconds for Twin 2. No signs or symptoms of dysarthria were noted during  
13 alternating motion rates, diadokokinetic rates, oral reading, or during an oral mechanism  
14 examination. For both twins, rigid videolaryngostroboscopy revealed marked concavity  
15 of the medial edges of the vocal folds bilaterally during abduction with prominent vocal  
16 processes. Incomplete mid-membranous glottal closure was observed as well as a  
17 spindle-shaped vibratory pattern during all phonation attempts at modal and high pitches.  
18 A prominent and persistent posterior glottal gap (i.e., in the interarytenoid region  
19 posterior to the vocal processes) was observed. Generalized laryngeal erythema was also  
20 observed. Findings were similar for both twins, with the exception that both the  
21 midmembranous and posterior gaps were more severe for Twin 1. Additionally, a small  
22 varix was observed on the lateral margin of the anterior portion of the right fold (Figure  
23 1).

1 *Surgical Management*

2 Twin 1 underwent a bilateral Hylaform medialization-injection procedure in June  
3 of 2005, followed by a bilateral Type 1 thyroplasty (3mm wedge implants) in August of  
4 2005. Subsequently, Twin 1 received a bilateral adipose fat injection performed by a  
5 second otolaryngologist in December of 2005. Based on patient report, Twin 1  
6 experienced temporary voice improvements with the Hylaform and fat injection  
7 procedures; however, these changes were modest and were not sustained. Twin 2  
8 underwent a bilateral Hylaform medialization-injection procedure in August of 2005. He  
9 subsequently reported minimal, temporary voice improvements with the procedure. (It  
10 should be noted that videostroboscopic comparisons from initial evaluation, pre-therapy,  
11 and post-therapy indicated increases in mid-membranous closure following the  
12 medialization procedures, although a marked posterior glottal gap persisted).

13 *Laryngeal Electromyography (LEMG)*

14 In order to examine potential neuromuscular effects and/or etiologies related to  
15 the twins' severe vocal fold bowing, LEMG was undertaken. For each twin, the  
16 examination procedure was identical, and was performed in January of 2006 (i.e.,  
17 following all surgical interventions/procedures). Prior to the LEMG procedure, a eutectic  
18 mixture of lidocaine (2.5%) and prilocaine (2.5%) was applied proximally on the neck in  
19 the region of the cricothyroid space. The otolaryngologist inserted modified bipolar  
20 hooked wire electrodes into the thyroarytenoid (TA) and lateral cricoarytenoid (LCA)  
21 musculature bilaterally. Electrode signals were verified using Valsalva and cough. EMG  
22 signals were captured and digitized using WINDAQ (version 2.44) acquisition software  
23 (DATAQ instruments, Akron, OH) simultaneously with the acoustic voice signal (head-

1 mounted microphone, AKG). The EMG signals were amplified and band-pass filtered,  
2 zero-meaned, rectified, and smoothed. The sample protocol included the following tasks,  
3 which were performed three times each (with the exception of quiet respiration): quiet  
4 respiration, swallow, cough, Valsalva, MPT (comfortable, soft, and loud), five-second  
5 (attempted) sustained /a/ (comfortable, soft, and loud), and laryngeal DDKs.

6 For purposes of EMG signal analysis, maximum amplitudes for each task were  
7 identified and were used for relative amplitude calculations using a similar methodology  
8 previously described and reported by Baker and colleagues (1998).<sup>7</sup> In brief, EMG  
9 signals were downsampled from 10 kHz to 1 kHz, and RMS smoothed using Matlab (The  
10 Mathworks, Inc.). Prephonatory and phonatory segments were isolated 500 and 100 ms  
11 prior to and following mic onset, respectively (duration = 1000 ms). Maximum  
12 amplitudes were identified for each muscle by examining the entire EMG signals for  
13 right (R) TA, left (L) TA, RLCA, and LLCA. Relative amplitudes were calculated as the  
14 absolute mean (in  $\mu\text{V}$ ), divided by the maximum signal, for each muscle.

### 15 *Behavioral Voice Therapy*

16 The twins underwent a four-session course of voice therapy from March to May  
17 of 2006. For each twin, the content and structure of the therapy sessions were identical,  
18 and were provided by the same clinician. Stimulability testing was undertaken involving  
19 a combination of manual circumlaryngeal techniques, resonance therapy training, and  
20 increased vocal effort and breath support was undertaken. The results from stimulability  
21 testing indicated a significant degree of hyperfunction and extralaryngeal muscle tension  
22 misregulation such that they were not judged to be suitable candidates for therapy  
23 involving the above treatment techniques. Because some recent evidence has been



1 offered in the literature to suggest that Vocal Function Exercises (VFEs) might be useful  
2 in improving voice production in the elderly a short course of behavioral therapy  
3 involving these techniques was undertaken for each of the twins.<sup>20</sup>

4 Session one included videolaryngostroboscopic assessment and a pre-treatment  
5 audio-recording, followed by the introduction to VFE. Minimal voice facilitation  
6 techniques, including laryngeal reposturing and increased resonance, were briefly used to  
7 stimulate an “engaged” tone required for VFE productions. Instructional audio-recordings  
8 and written instructions were provided, and the twins were instructed to practice twice  
9 daily. Sessions two and three involved clinician model, guided practice, and corrective  
10 feedback related to performance of the VFEs. Session four included a post-treatment  
11 videostroboscopic assessment, an audio-recording, and instructions for a maintenance  
12 tapering program of the exercises. The Voice Handicap Index was administered during  
13 sessions one and four for purposes of documenting functional disability related to the  
14 twins’ voice problems.<sup>21</sup>

#### 15 *Acoustic Analysis*

16 Audio-recordings were collected in May 2005 (initial evaluation), January of  
17 2006 (LEMG recordings), March of 2006 (pre-therapy) and May of 2006 (post-therapy)  
18 using a Sony digital video camera (DCR-TRV 350 NTSC Capture) and a Shure SM48  
19 multi-directional microphone (mouth-to-mic distance held constant at 2 in), and including  
20 *The Rainbow Passage*, three sustained /a/ tokens, maximum phonation time, and  
21 ascending and descending pitch glides. For purposes of acoustic analysis, audio signals  
22 were captured using the Computerized Speech Lab (version 4300B, Kay Elemetrics,  
23 Lincoln Park, NJ). Long-Term Average Spectrum (LTAS) analyses of the central

1 sentences of the rainbow passage were undertaken using a wide analysis bandwidth (128-  
2 bit) and Hamming window weighting, with a frequency range of 0 to 8,000 Hertz, and  
3 percent jitter, shimmer, and harmonic-to-noise ratio were calculated from the central 1  
4 sec of the second sustained /a/ tokens using the Multidimensional Voice Range Profile  
5 (MultiSpeech, version 3.1.1, Kay Elemetrics, Lincoln Park, NJ).<sup>22</sup>

6

## Results

### *Relative EMG Amplitudes*

Relative EMG amplitudes (RA) means and maximums for prephonatory and phonatory segments during sustained /a/ tokens at each loudness level are presented in Table 1. RA means for laryngeal DDKs (i.e., /a a a/ versus /ha ha ha/) are also presented. In general for Twin 1, prephonatory RAs were greater than phonatory segment RAs. This pattern was most obvious during loud sustained vowel attempts, and was fairly consistent across muscles and speaking tasks. Additionally, RAs for RLCA were notably greater than for RTA, LLCA, and LTA, across all speaking tasks. During loud phonation, maximum RAs were much greater than the mean RAs for all muscles. In general, Twin 2 had greater RA means and maximums as compared to Twin 1 (Figure 1), and prephonatory RAs were smaller than phonatory RAs. This finding was particularly notable during laryngeal DDKs. Consistently, for both twins, RA means for LTA are greater than RTA, and RLCA are greater than LLCA (Figure 2).

### *Acoustic Analysis*

Percent jitter, shimmer, and harmonic-to-noise ratio data for sustained vowel productions, as well as spectral mean and standard deviation (SD) from the LTAS, based on the reading passage, from audio-recordings during the initial assessment, the LEMG session, pre-therapy, and post-therapy are presented in Table 2. Maximum phonation time (MPT) is also provided. In general, no substantive and consistent differences were observed based on acoustic data from the initial assessment (observation 1) to the post-therapy assessment (observation 4) for either twin, nor were differences observed between the twins. In general, all acoustic measures reflected the severity/apperiodicity of

1 the voice signal (i.e., the twins remained severely dysphonic based on acoustic data  
2 throughout the case study report).

### 3 *Voice Therapy*

4 Videolaryngostroboscopic and self-perceived patient handicap data were obtained  
5 immediately prior to and following voice therapy. Midmembranous and posterior  
6 laryngeal glottal closure was observed to increase following voice therapy. Maximum  
7 adduction (closed phase) during modal phonation during videostroboscopic assessment is  
8 illustrated in Figures 2 and 3, pre- and post-therapy, respectively. Overall severity scores  
9 based on the Voice Handicap Index decreased markedly for Twin 1, less so for Twin 2  
10 (Table 3).

11

## Discussion

This case study provided a unique opportunity to closely examine the distinctions and similarities in elderly MZ twins with a diagnosis of vocal fold bowing and with slight variations in severity. Detailed case histories, diagnostic features, and treatment responsiveness were explored and compared to previous research related to vocal aging, including genetic and environmental factors. Auditory- and visual-perceptual, acoustic, and EMG measures were compared.

In general, the present study findings are consistent with previous research related to vocal aging and familial/heritability factors. The visual-perceptual features of prominent vocal processes, concavity of the vocal fold medial edges, and incomplete glottal closure observed in these MZ twins were consistent with those diagnostic phenomenological features previously described in the literature.<sup>1,2</sup> Perceptual characteristics of breathiness, weakness, and strain, in addition to severely reduced MPTs were also consistent with previous reports, although the twins in this study were judged to be very severely dysphonic. EMG results, including increased relative amplitude (RA) means and maximums from the present study, particularly those for Twin 1 (i.e., the severely dysphonic twin), are similar to those reported elsewhere.<sup>7</sup>

Previous studies related to genetic/heritability factors indicate that familial traits have been correlated with perceived vocal age, and  $F_0$  and MPT have been shown to be highly correlated in twin pairs, more so for MZ than DZ.<sup>6</sup> Audio-recording data for Twins 1 and 2 from the present investigation support these findings. It should be noted, however, that many twin studies involving the voice rely on registries for participant identification and recruitment, and therefore do not adequately reflect the clinical

1 populations to which findings might be generalized. Additionally, the nature and severity  
2 of Twin 1 and 2's dysphonia in the present investigation provide strong evidence for the  
3 influence of genetic factors, specifically those related to the aging process. Individuals  
4 with voice disorders have been shown to have a family history of dysphonia and shared  
5 genetics might partially account for the age-related structural and functional voice  
6 changes observed here.<sup>16</sup> Although it is unclear whether or not these changes are the  
7 result of the normal aging process or are pathological, the likely genetic influence on  
8 bowing observed in Twin 1 and 2 in this study is apparent.

9         Interestingly, differences between Twin 1 and Twin 2 with respect to  
10 environmental factors, as indicated in the psychosocial interview, were observed.  
11 Although the twins were reared together and spent the majority of their lifetimes in close  
12 geographic proximity, and had similar occupations and social histories, Twin 1 (i.e.  
13 extremely severe) had a self-reported substantial reduction in voice use since his wife  
14 passed away 10 years prior to his evaluation. Twin 1 also had markedly pathological  
15 gastroesophageal reflux, which has been theorized to influence or perhaps worsen  
16 dysphonia.<sup>23</sup> It is possible that this reduction in voice use, in addition to differences in  
17 reflux and other medical history, contributed to the discrepancy in the relative voice  
18 disorder severity, onset and progression of symptoms, and the degrees of dysphonia,  
19 bowing, glottal incompetence, and self-perceived voice handicap. In any case, this study  
20 provides evidence for the possible influence of environmental factors, in addition to  
21 heritability, on vocal fold bowing.

22         Perhaps the most striking finding in this study was the influence of behavioral  
23 voice therapy in improving glottic configuration/closure and reducing self-perceived

1 voice handicap in these twins. On initial evaluation, surgical intervention, including  
2 medialization-injection procedures and, in the case of Twin 1, thyroplasty, was  
3 considered to be an optimal primary treatment approach due to the severity of the  
4 mucosal changes and glottal closure patterns associated with vocal fold bowing.  
5 However, the lack of significant functional improvement following surgery prompted the  
6 recommendation for additional behavioral intervention. Although admittedly both twins  
7 in this study remained severely dysphonic after voice therapy, improvements in glottal  
8 closure configuration, as well as marked reductions in self-perceived voice handicap,  
9 were observed. This finding was somewhat surprising given that the option of behavioral  
10 voice therapy was initially rejected due to the severity of glottal incompetence. However,  
11 treatment response was consistent with some previous reports related to surgical and  
12 behavioral management of severe vocal fold bowing.<sup>24</sup> Due to significant age-related  
13 changes in the distinct organization and layered structure of the vocal folds, as well as  
14 general health characteristics that may influence vibratory properties, gross improvement  
15 in glottal closure alone might not result in optimal voice improvement in patients with  
16 bowing. Thus, regardless of bowing severity, behavioral voice therapy might be  
17 considered a primary or adjunctive treatment approach.

18 In summary, the present case study provides evidence to support both genetic and  
19 environmental influences on the aging voice. Although bowing is a frequent visual  
20 finding in patients diagnosed with presbylaryngis, incidence rates and evidence of  
21 differences between chronological and physiological aging might be the result of  
22 environmental factors, such as voice use patterns, in addition to heritability. Future

- 1 studies should continue to explore the relative contributions of genetic and environmental
- 2 influences on the aging voice.
- 3



1 Acknowledgements

2 Genetic testing was funded by Grant R01 DC4336 from the National Institutes of Health.

3

4

5

Figure Captions

1

2 *Figure 1 (a,b)*. Maximum closed phase during rigid videolaryngostroboscopy for Twin 1  
3 and Twin 2 during their initial evaluations, May 2005.

4 *Figure 2 (a,b)*. Maximum closed phase during rigid videolaryngostroboscopy for Twin 1  
5 and Twin 2 pre-therapy, March 2006.

6 *Figure 3 (a,b)*. Maximum closed phase during rigid videolaryngostroboscopy for Twin 1  
7 and Twin 2 post-therapy, May 2006.

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9

10

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20

1 *Table 1*

2 *Relative Amplitude (RA) means and maximums for prephonatory and phonatory segments*  
 3 *during sustained /ɑ/ and laryngeal DDKs during normal pitch and loudness (NPNL), soft*  
 4 *phonation, and loud phonation.*

Task	Twin 1				Twin 2			
	RTA Mean (Max)	LTA Mean (Max)	RLCA Mean (Max)	LLCA Mean (Max)	RTA Mean (Max)	LTA Mean (Max)	RLCA Mean (Max)	LLCA Mean (Max)
Prephonatory (vowel)								
<i>NPNL</i>	1.2 (4.4)	3.5 (11.8)	28.9 (53.4)	2.2 (5.2)	7.4 (28.4)	34.3 (66.2)	19.9 (33.0)	18.7 (55.5)
<i>Soft</i>	0.7 (1.3)	1.4 (8.6)	11.7 (19.7)	1.9 (3.1)	4.0 (6.5)	20.7 (32.3)	11.7 (28.1)	7.6 (15.3)
<i>Loud</i>	13.9 (59.1)	23.6 (80.6)	23.2 (83.2)	6.4 (30.0)	7.9 (33.8)	22.4 (33.1)	32.1 (55.7)	15.6 (31.5)
Phonatory (vowel)								
<i>NPNL</i>	1.0 (2.1)	2.2 (9.9)	11.7 (29.7)	2.3 (4.2)	12.0 (15.7)	25.6 (56.9)	26.1 (36.5)	11.1 (18.8)
<i>Soft</i>	0.6 (0.9)	0.4 (1.2)	6.8 (17.2)	1.6 (4.4)	15.7 (30.8)	37.5 (64.3)	22.7 (49.2)	14.3 (38.1)
<i>Loud</i>	3.7 (41.3)	5.9 (35.2)	15.4 (37.3)	2.6 (5.3)	14.0 (32.7)	24.9 (37.5)	28.2 (52.1)	18.5 (35.2)
Prephonatory (DDK)	5.9 (47.9)	10.2 (75.5)	15.4 (31.6)	2.8 (4.5)	7.6 (18.2)	8.9 (23.0)	6.5 (12.6)	3.2 (7.2)
Phonatory (DDK)	1.6 (5.3)	2.3 (13.6)	12.6 (35.9)	3.6 (6.4)	13.4 (24.1)	16.3 (25.2)	10.9 (25.1)	5.5 (9.6)

5  
6

1 *Table 2*  
 2 *MPT, percent jitter, shimmer, and harmonic-to-noise ratio, as well as spectral mean and*  
 3 *SD of the LTAS based on audio-recordings during the initial assessment, LEMG session,*  
 4 *pre-therapy, and post-therapy.*

Measure	Twin 1				Twin 2			
	5/05	1/06	3/06	5/06	5/05	1/06	3/06	5/06
F <sub>0</sub> (reading)	150	165	155	136	137	178	158	157
MPT (s)	1.0	1.0	1.3	1.1	1.7	3.6	3.4	3.8
% Jitter	4.1	5.2	2.6	3.8	3.7	1.2	1.4	2.0
% Shimmer	6.4	8.6	8.6	6.8	9.5	12.0	4.8	3.8
HNR	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Spectral Mean (Hz) (LTAS)	367.5	424.0	532.72	411.64	310.5	270.5	295.67	325.90
Spectral SD (LTAS)	4.16	827.5	1070.0	693.2	382.0	287.8	456.0	527.6

5  
6

1 *Table 3*

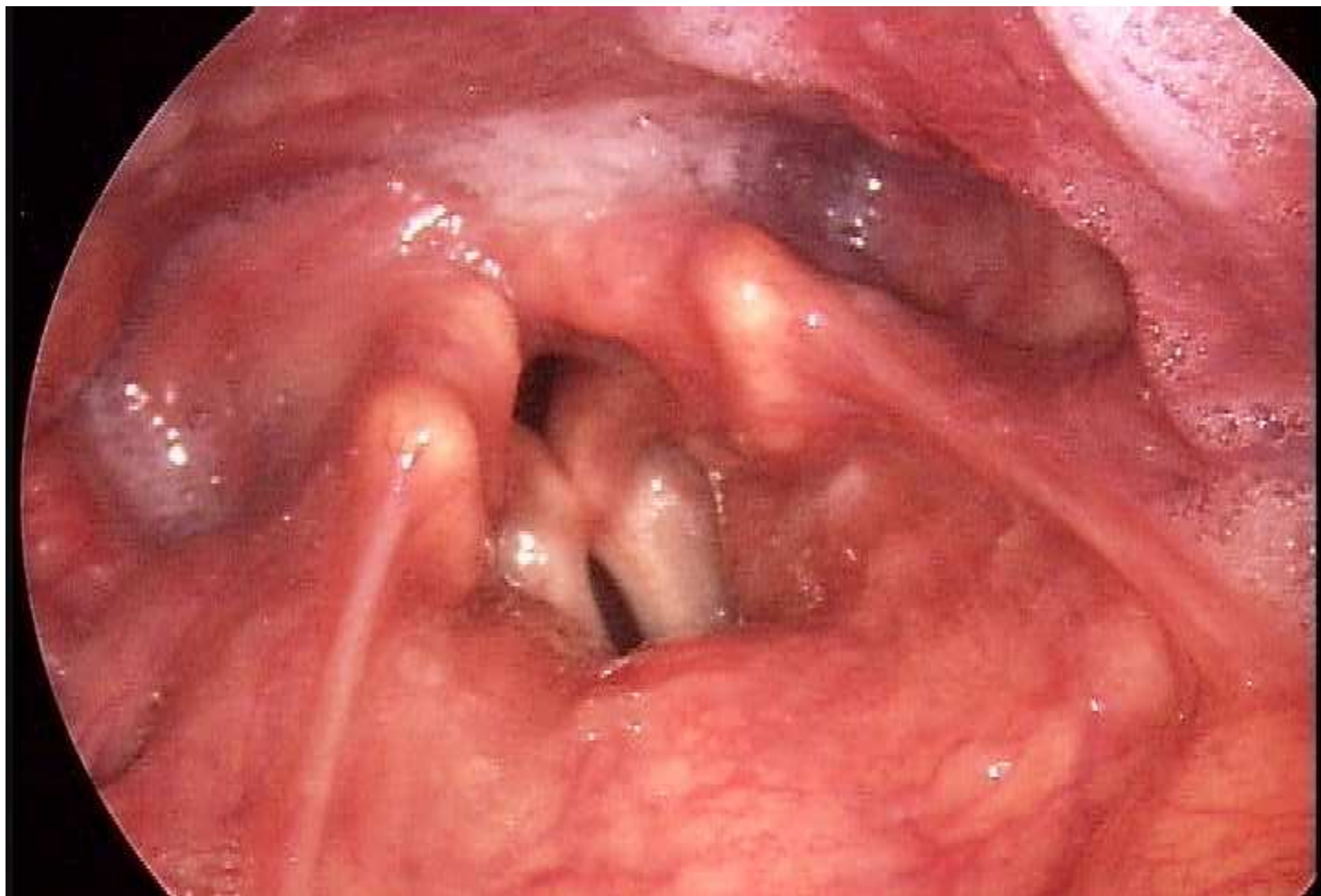
2 *Voice Handicap Index scores during the LEMG session, pre-therapy, and post-therapy.*

<b>Date</b>	<b>Voice Handicap Index: Total Score</b>	
	<b>Twin 1</b>	<b>Twin 2</b>
1/06	60	73
3/06	80	67
5/06	76	18

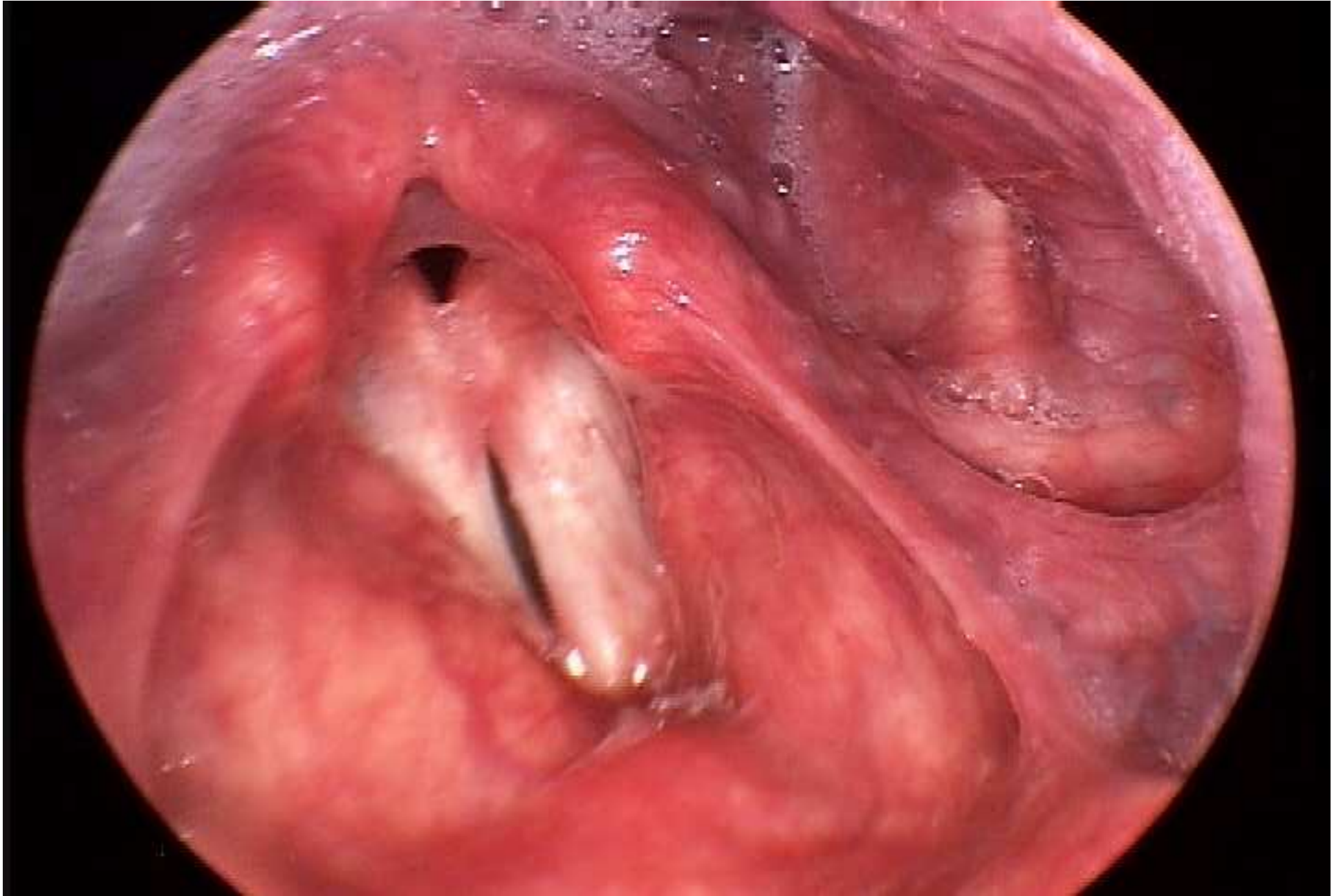
3



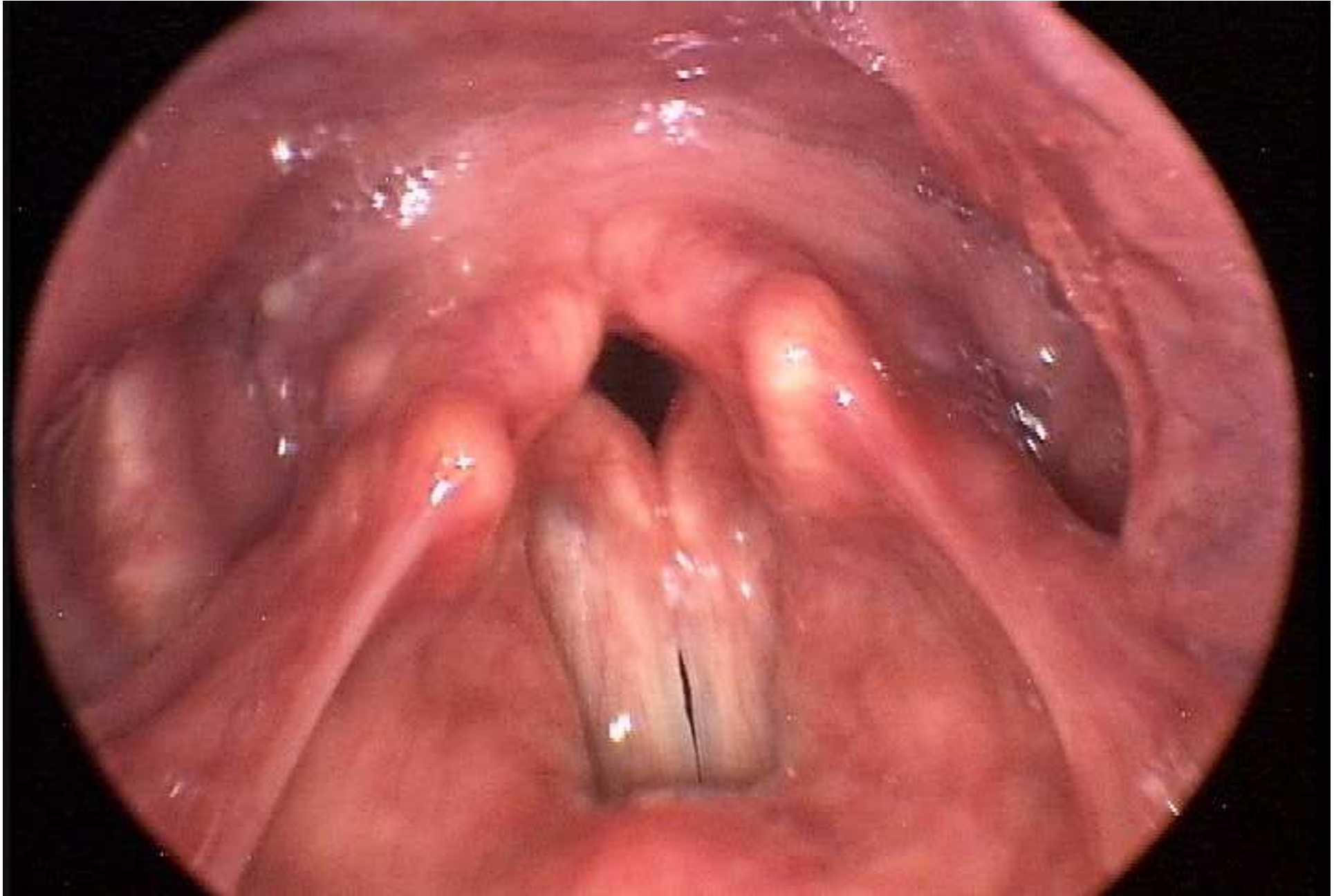
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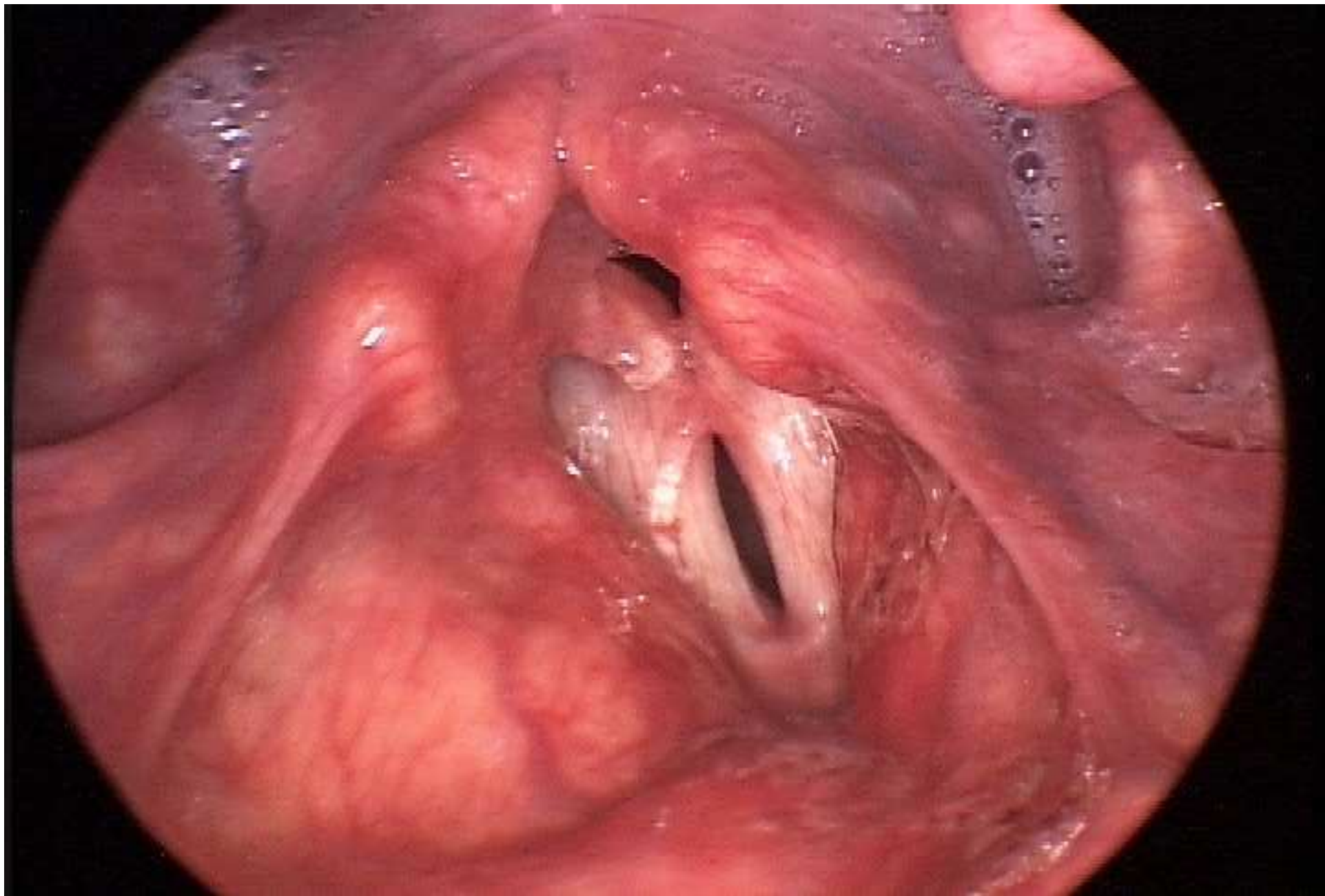
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