Breathing and Voice Quality After Surgical Treatment for Bilateral Vocal Cord Paralysis

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Objective: To evaluate long-term results of surgical treatment for bilateral vocal cord paralysis using objective and subjective measures of breathing and voice quality.

Design: Prospective cross-sectional case series.

Setting: Tertiary care otolaryngology and speech pathology referral center.

Patients: Ten patients with bilateral vocal cord paralysis who underwent surgical treatment between October 1996 and May 2006 at the Department of Otorhinolaryngology–Head and Neck Surgery, University of Würzburg, were examined at a mean of 27.2 months after surgery.

Main Outcome Measures: Glottal area, voice range profile, Voice Handicap Index, pulmonary function test results, Gettingen Hoarseness Diagram, microlaryngostroboscopic findings, chronic respiratory disease questionnaire, and European Organization for Research and the Treatment of Cancer quality-of-life questionnaire, including the head and neck module.

Results: Residual recurrent nerve function was seen in 9 of 10 patients. Pulmonary data varied widely and did not correlate with the size of the glottal area. Quality of life, subjective dyspnea, and physical functioning correlated with expiratory airflow measures. Voice range was reduced in all patients. High breathiness and reduced maximum phonation time led to increased Voice Handicap Index scores.

Conclusions: Microlaryngostroboscopic findings did not necessarily correlate with subjective dyspnea and vocal complaints. Reduction of inspiratory speaking efforts and acquisition of special breathing techniques improve airflow stability and effectiveness of respiration, leading to enhanced quality of life.

which was continued after surgery. The remaining patients were not using proton pump inhibitors or histamine blockers, such as omeprazole or ranitidine hydrochloride. Nine of 10 patients stopped smoking. Smoking was stopped more than 30 years and continued all the way up to surgery. Seven patients attended postoperative speech therapy to reduce inspiratory speaking efforts, and some patients continued to smoke after glottal widening. Seven patients attended postoperative speech therapy to reduce inspiratory speaking efforts, and some patients continued to smoke after glottal widening.

MICROLARYNGOSTROBOSCOPY

Microlaryngostroboscopy was performed and videotaped by one of us (S.B.). Laryngeal status was assessed by mucosal wave, residual movement, vocal cord position, additional pathologic findings, and evaluation of laryngeal function during swallowing of colored water. A frame in the state of maximum glottal opening was selected for subsequent analysis.

COMPUTATION OF GLOTTAL AREA INDEX

Measurement of genuine glottal area (GA) during microlaryngostroboscopy requires special laryngoscopes with scales that take angle, distortion, and resolution of the lenses into account. A relative measure of GA can be derived by analyzing a digital picture of maximum glottal opening and by computing the rate fraction compared with a standard measure. As shown in Figure 1, we used the distance between the posterior laryngeal commissure and the anterior vocal fold angle during maximum glottal opening as the standard distance in pixels. The GA index (GAindex) was defined as the fraction of GA of the maximum glottal opening as the standard distance in pixels.

### Table 1. Patient Characteristics and Interventions

<table>
<thead>
<tr>
<th>Patient No./Sex/Age, y</th>
<th>Cause of Bilateral Vocal Cord Paralysis</th>
<th>Intervention Date</th>
<th>Type</th>
<th>Side</th>
<th>Revision Date and Cause (Type)</th>
<th>Voice Rest, d&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Anti-inflammatory Medication</th>
<th>Postoperative Speech Therapy</th>
<th>Postoperative Follow-up, mo&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/M/70</td>
<td>Thoracic surgery</td>
<td>October 2005</td>
<td>PTC</td>
<td>Left</td>
<td>February 2002 for supervising (PTC)</td>
<td>3</td>
<td>Intravenous GC</td>
<td>Yes</td>
<td>13</td>
</tr>
<tr>
<td>2/F/71</td>
<td>Strumectomy</td>
<td>October 1996</td>
<td>PTC</td>
<td>Left</td>
<td>May 2003 for supervising (PTC)</td>
<td>5</td>
<td>Intravenous GC, inhalation of GC</td>
<td>No</td>
<td>42</td>
</tr>
<tr>
<td>3/M/61</td>
<td>Idiopathic</td>
<td>November 1998</td>
<td>PC</td>
<td>Right</td>
<td>May 2003 for supervising (PTC)</td>
<td>3</td>
<td>Intravenous GC</td>
<td>Yes</td>
<td>6</td>
</tr>
<tr>
<td>4/F/75&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Idiopathic</td>
<td>May 2006</td>
<td>PTC</td>
<td>Left</td>
<td>February 2005 for supervising (PTC)</td>
<td>7</td>
<td>Intravenous GC</td>
<td>Yes</td>
<td>21</td>
</tr>
<tr>
<td>5/F/65</td>
<td>Strumectomy</td>
<td>December 2004</td>
<td>PTC</td>
<td>Left</td>
<td>February 2005 for supervising (PTC)</td>
<td>7</td>
<td>Intravenous GC</td>
<td>Yes</td>
<td>22</td>
</tr>
<tr>
<td>6/F/73</td>
<td>Idiopathic</td>
<td>February 2002</td>
<td>PTC</td>
<td>Right</td>
<td>February 2005 for supervising (PTC)</td>
<td>3</td>
<td>Intravenous GC</td>
<td>Yes</td>
<td>57</td>
</tr>
<tr>
<td>7/F/60</td>
<td>Strumectomy</td>
<td>May 2006</td>
<td>PTC</td>
<td>Right</td>
<td>May 2006 for supervising (PTC)</td>
<td>3</td>
<td>Intravenous GC</td>
<td>Yes</td>
<td>7</td>
</tr>
<tr>
<td>8/F/73</td>
<td>Strumectomy</td>
<td>April 2006</td>
<td>PTC</td>
<td>Left</td>
<td>August 2003 for polyp (resection)</td>
<td>3</td>
<td>Intravenous GC</td>
<td>Yes</td>
<td>22</td>
</tr>
<tr>
<td>9/F/76</td>
<td>Strumectomy</td>
<td>June 2003</td>
<td>PTC</td>
<td>Right</td>
<td>August 2003 for polyp (resection)</td>
<td>5</td>
<td>Intravenous GC, inhalation of GC</td>
<td>No</td>
<td>40</td>
</tr>
<tr>
<td>10/F/41</td>
<td>Strumectomy</td>
<td>May 2006</td>
<td>PTC</td>
<td>Left</td>
<td>August 2003 for polyp (resection)</td>
<td>5</td>
<td>Intravenous GC, inhalation of GC</td>
<td>No</td>
<td>40</td>
</tr>
</tbody>
</table>

Abbreviations: Inhalation of GC, inhalation of budesonide; intravenous GC, single dose of prednisolone-21-hydrogen succinate (250-500 mg); PC, posterior cordectomy; PTC, posterior transverse cordotomy.

<sup>a</sup> Mean (SD) of 4.2 (1.7) days.

<sup>b</sup> Mean (SD) of 27.2 (20.0) months, as referred to last surgical vocal cord procedure.

<sup>c</sup> Smoker.

For each patient, a voice range profile (phonetogram) was recorded using commercially available equipment (lingWAVES GmbH, Hoemburg, Germany). Full calibration and verification of equipment were performed before each set of tests. Measurements included registration of flow-volume loops during forced ventilation and body plethysmography. We analyzed forced vital capacity (FVC), forced expiratory volume in the first second of expiration (FEV₁), peak expiratory flow (PEF), forced inspiratory volume in the first second of inspiration (FIW₁), and peak inspiratory flow (PIF), as well as intrathoracic gas volume, total airway resistance, resistance during inspiration, and resistance during expiration.

### Subjective Measures

During clinical assessment, all patients were asked whether they experienced shortness of breath at rest or at exertion. However, throughout the entire analysis, we interviewed patients regarding subjective dyspnea and asked whether they were using medication for dyspnea.

### Objective Measures

Pulmonary function tests were administered by a single operator in the Department of Medicine using a commercially available device (JAEGER Master Screen Body; VIASYS Healthcare GmbH, Hoemburg, Germany). Full calibration and verification of equipment were performed before each set of tests. Measurements included registration of flow-volume loops during forced ventilation and body plethysmography. We analyzed forced vital capacity (FVC), forced expiratory volume in the first second of expiration (FEV₁), peak expiratory flow (PEF), forced inspiratory volume in the first second of inspiration (FIW₁), and peak inspiratory flow (PIF), as well as intrathoracic gas volume, total airway resistance, resistance during inspiration, and resistance during expiration.

### RESPIRATORY ASSESSMENT

#### Objective Measures

Pulmonary function tests were administered by a single operator in the Department of Medicine using a commercially available device (JAEGER Master Screen Body; VIASYS Healthcare GmbH, Hoemburg, Germany). Full calibration and verification of equipment were performed before each set of tests. Measurements included registration of flow-volume loops during forced ventilation and body plethysmography. We analyzed forced vital capacity (FVC), forced expiratory volume in the first second of expiration (FEV₁), peak expiratory flow (PEF), forced inspiratory volume in the first second of inspiration (FIW₁), and peak inspiratory flow (PIF), as well as intrathoracic gas volume, total airway resistance, resistance during inspiration, and resistance during expiration.

#### EVALUATION OF VOICE

#### Objective Assessment

For each patient, a voice range profile (phonetogram) was recorded using commercially available equipment (lingWAVES GmbH, Hoemburg, Germany).
Phonetogram Plus; lingCOM GmbH, Forchheim, Germany). Analysis included minimum and maximum intensity in decibels, dynamic range in decibels, minimum and maximum frequency in hertz, frequency range on a logarithmic halftone scale, and the mean fundamental frequency. Maximum phonation time in seconds was recorded during voicing of the vowel /a/ after maximal inspiration at spontaneous comfortable pitch and loudness. The phonatory quotient was calculated by dividing vital capacity in liters by maximum phonation time in seconds. Voice acoustics were evaluated using standard variables such as jitter and shimmer, as well as the Göttingen Hoarseness Diagram (GHD). The GHD is a voice analysis software program that was developed by Michaelis et al9 and provides objective voice analysis even in irregular voices. The recording protocol requires phonation of 4 series of the vowels /ε/, /æ/, /ɛ/, /u/, and /ε/, during which the patient phonates at comfortable pitch (first series), at low pitch (second series), at high pitch (third series), and again at comfortable pitch after reading a standardized text passage (fourth series [afterload]). The stationary part of the signal is used for computerized analysis. Results are plotted in a 2-dimensional diagram, where x values reflect aperiodicity of the voice (irregularity component), calculated from jitter, shimmer, and period correlation, and y values represent the noise component of the signal, calculated from the glottal-to-noise excitation ratio. To allow easy interpretation, ellipses are used to illustrate the distribution of single-vowel measures (28 vowels per test). The center of the ellipses represents the mean value of the noise and irregularity component, while semiaxes are defined by the associated standard deviation. The GHD offers a graphic illustration of voice quality that has proven to be statistically significantly different for specific pathophysiologic phonation conditions.10

Subjective Assessment

A standardized reading passage recorded during measurement of the GHD was evaluated by 6 experienced listeners (4 phoniatric specialists and 2 speech therapists [S.B. and co-workers]) according to a simplified version of the GRBAS scale, which is widely used in German-speaking clinics. Grades of hoarseness (G), roughness (R), and breathiness (B) are reported using a 4-point scale ranging from 0 (no deviance) to 3 (severe deviance). Speech samples were presented anonymously in random order. Within the test set, 1 sample was presented twice to evaluate intrapersonal judgment reliability.

To assess patients' voice-related quality of life, the German version of the Voice Handicap Index (VHI), validated by Nawka et al11 was applied. The questionnaire contains 30 items in 3 subscales (functional, emotional, and physical [10 items per subscale]), designed to quantify patients' self-assessment of everyday voice handicap. Answers are given on a 5-point scale ranging from 0 (never) to 4 (always). The overall VHI score (raw score) can be used to grade subjective handicap from 0 (no handicap [raw score, 0-14]) to 3 (severe handicap [raw score, 51-120]).

ASSESSMENT OF OVERALL HEALTH AND QUALITY OF LIFE

The European Organization for Research and the Treatment of Cancer quality-of-life questionnaire (core questionnaire, QLQ-C30 version 3.0),12 including the head and neck module (QLQ-H&N35), was used for assessment of overall and ear, nose, and throat–specific quality of life. The core questionnaire is composed of 30 items on quality of life and various symptom and function scales, while the head and neck module consists of 35 symptom-related questions. On the symptom and function scales, answers are binominal (yes or no) or on a scale ranging from 1 (not at all) to 4 (very much).

Quality of life is assessed by an analog scale ranging from 1 (very bad) to 7 (excellent). For interpretation of scores, data from the QLQ-C30 and QLQ-H&N35 subdomains were compared with published reference values,13,14 as recommended by the authors of the questionnaire.12 Michelson et al13 presented QLQ-C30 data from a large sample (range, 1536-1613) from a healthy Swedish population. Bjordal et al12 published QLQ-C30 and QLQ-H&N35 scores from a cohort of patients with head and neck cancer grouped into newly diagnosed (n=204), recurrent (n=38), and disease-free (n=360) subjects.

STATISTICAL ANALYSIS

Normal distribution of data was verified. Correlation analyses were performed among size of GA, PFT findings, objective data...
Table 2. Pulmonary Function Test Results and Glottal Area Indexes (GAis)

<table>
<thead>
<tr>
<th>Patient No./Sex</th>
<th>FVC (% Predicted)</th>
<th>FEV1 (% Predicted)</th>
<th>Peak Expiratory Flow (% Predicted)</th>
<th>FIV</th>
<th>Peak Inspiratory Flow</th>
<th>Total Airway Resistance (During Inspiration)</th>
<th>Resistance During Inspiration</th>
<th>Resistance During Expiration</th>
<th>FVC/FEV1</th>
<th>Intrathoracic Gas Volume (% Predicted)</th>
<th>GAi</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/M</td>
<td>1.66 (45.0)</td>
<td>1.27 (44.7)</td>
<td>3.26 (42.6)</td>
<td>1.64</td>
<td>2.26</td>
<td>0.64 (212.2)</td>
<td>0.71</td>
<td>0.61</td>
<td>76.28</td>
<td>2.39 (67.5)</td>
<td>0.102</td>
</tr>
<tr>
<td>2/F</td>
<td>2.42 (103.0)</td>
<td>1.84 (94.7)</td>
<td>2.49 (44.8)</td>
<td>1.40</td>
<td>1.76</td>
<td>0.3 (166.3)</td>
<td>0.41</td>
<td>0.51</td>
<td>75.99</td>
<td>3.69 (139.0)</td>
<td>0.071</td>
</tr>
<tr>
<td>3/M</td>
<td>3.72 (90.9)</td>
<td>1.54 (47.7)</td>
<td>1.58 (19.2)</td>
<td>1.08</td>
<td>1.34</td>
<td>0.21 (70.1)</td>
<td>0.22</td>
<td>0.18</td>
<td>41.25</td>
<td>3.59 (101.6)</td>
<td>0.214</td>
</tr>
<tr>
<td>4/F</td>
<td>4.48 (114.8)</td>
<td>1.81 (102.7)</td>
<td>4.03 (75.5)</td>
<td>1.84</td>
<td>2.39</td>
<td>0.37 (123.3)</td>
<td>0.34</td>
<td>0.46</td>
<td>73.19</td>
<td>3.26 (124.6)</td>
<td>0.077</td>
</tr>
<tr>
<td>5/F</td>
<td>2.01 (78.8)</td>
<td>1.75 (82.2)</td>
<td>3.56 (61.4)</td>
<td>0.84</td>
<td>1.06</td>
<td>0.47 (157.4)</td>
<td>0.44</td>
<td>0.44</td>
<td>87.21</td>
<td>2.13 (79.6)</td>
<td>0.153</td>
</tr>
<tr>
<td>6/F</td>
<td>1.57 (71.0)</td>
<td>1.28 (70.2)</td>
<td>1.87 (34.6)</td>
<td>0.56</td>
<td>0.75</td>
<td>0.95 (316.3)</td>
<td>1.01</td>
<td>0.81</td>
<td>81.23</td>
<td>3.05 (116.7)</td>
<td>0.124</td>
</tr>
<tr>
<td>7/F</td>
<td>3.45 (122.5)</td>
<td>2.59 (108.9)</td>
<td>2.72 (44.5)</td>
<td>0.60</td>
<td>1.61</td>
<td>0.46 (154.4)</td>
<td>0.45</td>
<td>0.36</td>
<td>75.09</td>
<td>2.78 (101.7)</td>
<td>0.073</td>
</tr>
<tr>
<td>8/F</td>
<td>3.27 (115.3)</td>
<td>2.53 (106.6)</td>
<td>3.82 (62.0)</td>
<td>1.24</td>
<td>1.64</td>
<td>0.34 (133.3)</td>
<td>0.28</td>
<td>0.48</td>
<td>77.38</td>
<td>3.32 (113.5)</td>
<td>0.080</td>
</tr>
<tr>
<td>9/F</td>
<td>2.51 (97.4)</td>
<td>2.07 (97.0)</td>
<td>4.46 (76.2)</td>
<td>1.24</td>
<td>1.64</td>
<td>0.33 (109.4)</td>
<td>0.27</td>
<td>0.43</td>
<td>82.54</td>
<td>2.84 (100.1)</td>
<td>0.166</td>
</tr>
<tr>
<td>10/F</td>
<td>2.81 (95.1)</td>
<td>2.22 (87.5)</td>
<td>2.99 (47.9)</td>
<td>0.76</td>
<td>1.60</td>
<td>0.72 (241.6)</td>
<td>0.74</td>
<td>0.65</td>
<td>78.96</td>
<td>1.94 (76.4)</td>
<td>0.163</td>
</tr>
<tr>
<td>Mean</td>
<td>3.25 (93.38)</td>
<td>1.89 (84.22)</td>
<td>3.08 (50.87)</td>
<td>1.12</td>
<td>1.61</td>
<td>0.50 (166.4)</td>
<td>0.49</td>
<td>0.49</td>
<td>73.19</td>
<td>2.99 (102.07)</td>
<td>0.122</td>
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<tr>
<td>SD</td>
<td>0.73 (23.47)</td>
<td>0.47 (23.17)</td>
<td>0.93 (17.97)</td>
<td>0.43</td>
<td>0.49</td>
<td>0.42 (72.76)</td>
<td>0.25</td>
<td>0.17</td>
<td>12.52</td>
<td>0.69 (22.56)</td>
<td>0.002</td>
</tr>
</tbody>
</table>

Abbreviations: FEV1, forced expiratory volume in the first second of expiration; FIV, forced inspiratory volume in the first second of inspiration; FVC, forced vital capacity.

RESULTS

All patients experienced various degrees of hoarseness and dyspnea during moderate physical activity but denied difficulties during deglutition. Patients’ reports on the number of stairs they were able to climb gave unreliable results. Random testing (climbing stairs in the clinic, supervised by medical staff) revealed that subjects were often overestimating or underestimating their true capacity.

MICROLARYNGOSTROBOSCOPY

Minimal vocal cord movement was present in 8 patients (6 unilaterally and 2 bilaterally), and all showed residual mucosal waves. In 1 patient, unilateral mucosal wave without visible vocal cord movement was evident. Deglution of colored water was undisturbed in all patients.

GLOTTAL AREA INDEX

In healthy subjects, the GAi ranged from 0.286 to 0.716 (mean [SD], 0.438 [0.099]). No statistically significant difference between men and women was found. Compared with the control group, patients with BVCP had a statistically significantly lower GAi (range, 0.071-0.214; mean [SD], 0.122 [0.050]; P < .001). Glottal area was sufficient for low to moderate physical activity in 9 of 10 patients. One woman had dyspnea at rest and had the lowest GAi (0.071) in the group. Additional surgery was recommended to relieve airway obstruction.

RESPIRATORY ASSESSMENT

Objective Measures

An overview of respiratory measures is given in Table 2. The mean PFT results were within normal values for FVC and for intrathoracic gas volume. Expiratory and inspiratory flow measures (FEV1, PEF, FIV1, and PIF) were reduced, while resistance (total airway resistance, resistance during inspiration, and resistance during expiration) was increased. No statistically significant correlation was found between PFT results and the GAi. Although patient 3 had the highest GAi (0.214) in the group, and resistance within normal values, he exhibited the smallest PEF (1.58 [19.2% of predicted]) in the group and a small PIF (1.34). In contrast, patient 2, with the lowest GAi (0.071) in the group, had a mean PEF of 2.49 (44.8% of predicted) and the third largest PIF (1.76) in the BVCP group, while resistance was moderately increased.

Subjective Measures

One patient did not return the questionnaire. Among the returned forms, no data were missing. In the dyspnea domain of the CRQ-SAS, patients reported themselves on average to be “quite a bit short of breath” (mean [SD] score, 3.24 [0.51]). Dyspnea was worst when subjects were “angry or upset” (mean [SD] score, 2.25 [0.89] [“very short of breath”]). In general, patients were “moderately tired” (mean [SD] score, 3.67 [1.17]) and “some of the time” were able to master their breathing difficulties (mean [SD] score, 4.44 [0.58]). Emotional functioning was reported to be “a good bit of the time” impaired (mean [SD] score, 3.54 [0.63]). A positive correlation (r = 0.75, P = .02) was found between the CRQ-SAS dyspnea score and PEF. In addition, a statistically significant correlation between self-reported mastery and FIV1 (r = 0.73, P = .03), as well as between self-reported mas-
tery and resistance during inspiration \( (r = -0.70, P = .04) \), was evident.

**EVALUATION OF VOICE**

**Objective Assessment**

An overview of voice quality measures is given in Table 3. Voice range was reduced in all patients but varied widely. Patient 8 had normal values in all categories except shimmer (score, 15.8) and aerodynamics (maximum phonation time, 9.3 seconds; phonatory quotient, 0.35 L/s). Computerized voice analysis (based on the GHD) showed a mean (SD) vowel irregularity of 6.12 (1.12) and a mean (SD) noise component of 2.91 (0.70). Ellipses reflecting the distribution of means (center of ellipses) and the standard deviations (semiaxes) are shown in Figure 2. Only complete data sets based on analysis of 28 vowels per patient were included. For comparison, published data\(^\text{10}\) of normal and aphonic voices, as well as of subjects with untreated vocal cord paralysis, were added. Analysis revealed statistically significant differences between the BVCP group and normal voices (irregularity, \( P < .001 \); noise, \( P = .001 \)), aphonic voices (irregularity, \( P < .001 \); noise, \( P = .007 \)), and voices of patients with untreated vocal cord paralysis (irregularity, \( P = .01 \); noise, \( P = .01 \)).

**Subjective Assessment**

Perceptive voice evaluation according to the GRBAS scale varied widely between listeners. Patients' scores ranged from G\(_1\)R\(_3\)B\(_0\) to G\(_3\)R\(_3\)B\(_2\), with mean (SD) values of 2.0 (0.67) for G, 1.6 (0.7) for R, and 1.4 (0.84) for B. Self-reported voice handicap was in general moderate to severe (mean [SD],

### Table 3. Objective Voice Evaluation, Voice Handicap Index (VHI) Scores, and G"ottingen Hoarseness Diagram Grade

<table>
<thead>
<tr>
<th>Patient No./Sex</th>
<th>Aerodynamics</th>
<th>Acoustics</th>
<th>Subjective Self-evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/M</td>
<td>Maximum Phonation Time, s</td>
<td>Minimum Intensity, dB</td>
<td>Maximum Intensity, dB</td>
</tr>
<tr>
<td>2/F</td>
<td>2.8</td>
<td>0.59</td>
<td>68</td>
</tr>
<tr>
<td>3/F</td>
<td>6.9</td>
<td>0.23</td>
<td>57</td>
</tr>
<tr>
<td>4/F</td>
<td>1.9</td>
<td>1.96</td>
<td>51</td>
</tr>
<tr>
<td>5/F</td>
<td>3.2</td>
<td>0.78</td>
<td>56</td>
</tr>
<tr>
<td>6/F</td>
<td>2.8</td>
<td>0.72</td>
<td>58</td>
</tr>
<tr>
<td>7/F</td>
<td>3.3</td>
<td>0.35</td>
<td>51</td>
</tr>
<tr>
<td>8/F</td>
<td>3.3</td>
<td>0.76</td>
<td>62</td>
</tr>
<tr>
<td>9/F</td>
<td>8.3</td>
<td>0.34</td>
<td>54</td>
</tr>
<tr>
<td>10/F</td>
<td>9.3</td>
<td>0.35</td>
<td>51</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>4.6 (2.7)</td>
<td>0.75 (0.50)</td>
<td>59 (7)</td>
</tr>
</tbody>
</table>

*Abbreviations: B, breathiness; G, hoarseness; NA, patient unable to perform test; R, roughness.

*Incomplete vowel set (7 of 28).
those in healthy controls (with scores in patients with BVCP (mean [SD], 58.67 [15.01])
cal functioning and social functioning were impaired as well,
healthy subjects (mean [SD], 66.67 [35.14] for dyspnea) than in
patients with BVCP such as voice-related problems. Concerning evaluation of physical capacity, it was an un-
markers for subjective dyspnea, but no single lung func-
tions such as the 6-minute walk test.21 Analysis of maximum glottal opening revealed similar GAIs in the BVCP group, which were statistically significantly lower than those in healthy controls. In contrast, outcomes in terms of voice quality and dyspnea varied widely.

From a respiratory point of view, BVCP causes variable extrathoracic stenosis, resulting in reduced inspiratory flow measures (PIF and FIV) and almost normal expiratory flow measures (PEF and FEV) reflected by PEF/PIF ratios greater than 1.18 Although PEF was reduced in all patients, the PEF/PIF ratio exceeded 1 (mean [SD], 2.09 [0.69]). No statistically significant correlation was found between the GAi and PFT results. Because flow measures are based on forced maneuvers and the GAi was derived from pictures during quiet breathing, additional factors might apply such as increased turbulence or the Bernoulli effect (passive movement of paralyzed vocal cord into the line of flow due to suction during inspiration), which were not evident during microlaryngostroboscopy. Previous studies5,6 on surgical outcomes compared preoperative and postoperative PFT results, demonstrating a statistically significant relationship between glottal widening and an increase in flow measures and a respective decrease in airway resistance. Our study did not investigate PFT changes caused by surgical treatment but compared the present glottal status with PFT results and subjective dyspnea symptoms. Because no correlations between the GAi and lung function measures were found, the GAi cannot serve as a predictor of pulmonary function or subjective dyspnea. However, because GAi measurement was based on microlaryngostroboscopy findings during quiet breathing, future investigations should evaluate the effect of forced inspiration and expiration on GA in patients with BVCP.

For surgical outcomes, the effects on a patient’s quality of life and physical capacity are of major interest. In patients with chronic pulmonary diseases, previous studies19 tried to establish physiologic measures as surrogate markers for subjective dyspnea, but no single lung function measure sufficiently described the effect of shortness of breath on patients’ daily life. In addition, changes in subjective dyspnea (eg, during rehabilitation or short-term bronchodilatation) did not result in corresponding changes in PFT results (for a review, see Ries19). Therefore, the use of PFTs should be reconsidered. Ries19 suggests that dyspnea-specific quality-of-life questionnaires would be more suitable measures. The CRQ-SAS scores of our patients with BVCP in the dyspnea, fatigue, and mastery domains were similar to those reported by subjects with chronic obstructive pulmonary disease.20 In the emotional domain, our patients with BVCP scored statistically significantly lower than the subjects with chronic obstructive pulmonary disease (P = 0.01),20 indicating reduced emotional functioning. This may be related to additional handicaps in patients with BVCP such as voice-related problems. Concerning evaluation of physical capacity, it was an unreliable measure for subjects to state the number of stairs that he or she is able to climb without shortness of breath. Patient ability to recall this information varies, and true capacity was often overestimated or underestimated. Further studies should include more reliable exercise measures such as the 6-minute walk test.21 Perceptive voice evaluation according to the simplified GRBAS scale varied widely. Intrapersonal reliability was
weak. In some cases, experienced listeners obtained different scores when listening twice to an identical voice sample. Computerized voice analysis using the GHD has been proven to be a useful tool for discrimination of pathologic voices and for longitudinal voice evaluation.10 Statistically significant differences of objective voice measures were found between our subjects and published data of normal voices, aphonias, and voices of patients with untreated vocal cord paralysis.10 Similar results were published by Olthoff et al,4 who examined 17 patients who had been treated by laser surgical bilateral posterior cordectomy. Comparison of their postoperative noise and irregularity component findings with those of our cohort revealed no statistically significant difference (P=.87 for irregularity; P=.83 for noise).

In a single case of mild voice pathologic function, self-assessed VHI score corresponded to GHD position. The remaining patients, who reported themselves as being moderately to severely impaired, could not be distinguished using the GHD data. Further studies, including a larger number of subjects, should investigate the relationship between VHI scores and GHD position. In patients in whom speech therapy led to effective changes in breathing technique and speaking habits, a positive effect on subjective physical capacity and voice quality was visible. Detailed information about how these techniques can improve quality of life should be provided during consultations to increase patients’ motivation for speech and breathing therapy.

Surgical treatment of BVCP is a safe and effective method to improve patients’ quality of life. However, microlaryngo-gastrostroboscopic findings did not necessarily correlate with subjective dyspnea symptoms, PFT results, and vocal complaints. Specific quality-of-life questionnaires can be useful for evaluating the everyday effect of glottal widening. Voice rehabilitation should be monitored objectively using computerized voice analysis, which is superior to perceptual voice evaluation. Reduction of inspiratory speaking efforts and acquisition of special breathing techniques improve airflow stability and effectiveness of respiration, leading to enhanced quality of life and patient satisfaction.

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REFERENCES


CONCLUSIONS

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