Original Investigation

Comparison of Voice and Swallowing Parameters After Endoscopic Total and Partial Arytenoidectomy for Bilateral Abductor Vocal Fold Paralysis
A Randomized Trial

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IMPORTANCE Total arytenoidectomy is claimed to increase risk of aspiration and cause more voice loss than other operations performed for bilateral abductor vocal fold paralysis (BVFP). However, objective evidence for such a conclusion is lacking. There is no study comparing swallowing and voice after total and partial arytenoidectomy.

OBJECTIVE To compare voice and swallowing parameters after endoscopic total and partial arytenoidectomy for BVFP.

DESIGN, SETTING, AND PARTICIPANTS In this prospective, randomized, double-blind, case-control study conducted at a tertiary referral university, the study population comprised 20 patients with BVFP.

INTERVENTIONS Endoscopic total and partial arytenoidectomy.

MAIN OUTCOMES AND MEASURES Decannulation, duration of operation, Voice Handicap Index, acoustic and aerodynamic analysis, postoperative breathing ability, subjective comparison of preoperative and postoperative voice, speech intensity, and functional outcome swallowing scale.

RESULTS Median duration of partial and total arytenoidectomies were 59 and 49 minutes, respectively. This difference was statistically significant ($P = .04$). Comparisons of preoperative and postoperative Voice Handicap Index, acoustic and aerodynamic measures, postoperative breathing ability, subjective comparison of preoperative and postoperative voice, speech intensity, and functional outcome swallowing scale were not statistically significantly different between both groups.

CONCLUSIONS AND RELEVANCE Endoscopic total and partial arytenoidectomy are very successful static surgical options for BVFP. Partial takes longer than total arytenoidectomy. They both provide a comfortable airway, acceptable voice, and acceptable deglutition. It may be a sound practice to perform partial arytenoidectomy initially for primary BVFP cases and reserve total arytenoidectomy for revision cases.

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Bilateral abductor vocal fold paralysis (BVFP) has always been a serious health problem for patients and a challenge for surgeons. It has resulted in airway obstruction, aspiration, swallowing disturbance, and voice change. All of these have had a notable impact on lowering quality of life. Among many treatment options available for BVFP, endoscopic partial and total arytenoidectomy have had the highest success rate for alleviating airway obstruction.[1]

However, there have been claims that total arytenoidectomy leads to aspiration problems postoperatively and disturbs voice significantly.[2] In traditional endoscopic total arytenoidectomy, after removal of arytenoid cartilage, its bed is cauterized with electrocautery and is left to secondary scar contracture. Alternatively, with the use of a carbon dioxide laser, arytenoid cartilage is evaporated together with its overlying mucosa, leaving a charred open wound, which has to epithelialize by secondary intention. A scarred surgical area is not expected to have sensation; hence, aspiration is a big potential problem. Furthermore, loss of arytenoid height may open an easy flow pathway for hypopharyngeal secretions to enter the laryngeal lumen. Combination of a lack of mucosal sensation with a loss of arytenoid height may significantly worsen aspiration problem. These potential risks put total arytenoidectomy out of favor and led to the development of partial arytenoidectomy techniques.

Is it really the case? Does total arytenoidectomy really increase the risk of aspiration and lead to swallowing problems? Does partial arytenoidectomy protect against aspiration while providing adequate airway? Voice disturbance is another issue after total arytenoidectomy. Total arytenoidectomy is claimed to cause more voice loss than any other operation performed for BVFP.[2] However, objective evidence for such a conclusion is lacking. We could not find a study comparing swallowing and voice after total and partial arytenoidectomy. The present study was carried out as a preliminary study to compare voice and swallowing parameters after endoscopic total and partial arytenoidectomy for BVFP.

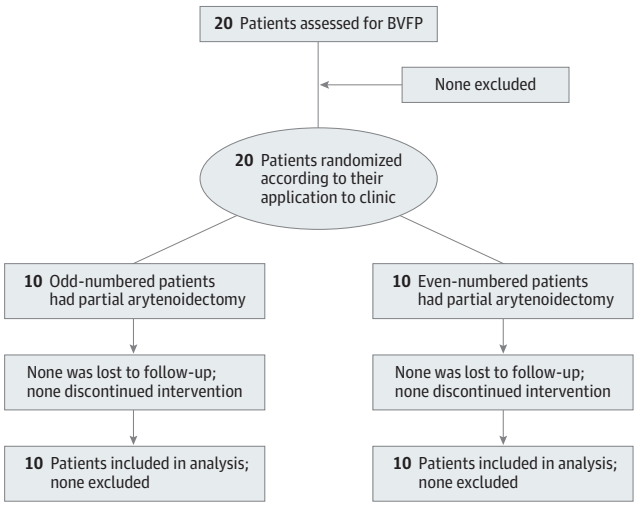
Methods

Twenty otherwise healthy patients (15 female and 5 male) with BVFP were included in the study. Their ages ranged between 23 and 73 years, with a median age of 52 years. The cause of paralysis was thyroidectomy in 19 patients and spinal muscular atrophy in 1 patient. This study was approved by the Hacettepe University institutional ethics committee and was performed in the laryngology unit of our university hospital otolaryngology department.

Twenty consecutive patients underwent arytenoidectomy, with odd-numbered patients undergoing partial arytenoidectomy and even-numbered patients, total arytenoidectomy. The operative technique involved endoscopic total or partial arytenoidectomy + medially based mucosal advancement flap + vocal fold lateralization with endoscopic microsuture (**Figure 1**). For total arytenoidectomy (**Figure 2**), the technique was described in detail by Yilmaz.[1] For partial arytenoidectomy (**Figure 3**), vocal process and anterior half of body of arytenoid was evaporated with carbon dioxide laser, preserving posterior half of body and muscular process; interarytenoid, thyroarytenoid, and lateral cricoarytenoid muscle attachments were severed, preserving posterior cricoarytenoid muscle attachment to the posterior face of muscular process. Similarly, medially based mucosal advancement flap was sutured posterolaterally over the remnant body of arytenoid, and vocal fold lateralization was performed with endoscopic microsuture by suturing the membranous vocal fold lateral to the remnant of body of arytenoid, thus covering all open wounds.

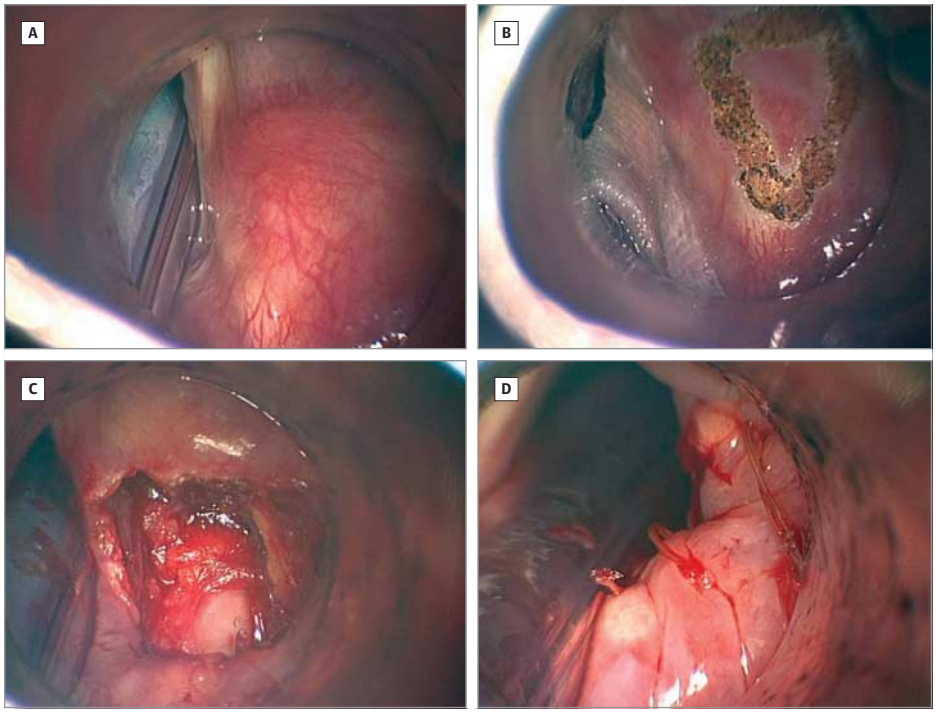
All patients were primary (unoperated) cases. Sixteen patients had dyspnea without tracheotomy, and none of these patients required tracheotomy postoperatively. Four patients had tracheotomy, and all were decannulated in the operating room right after arytenoidectomy. All were symptom free or decannulated after 1 surgery.

Figure 1. Flow Diagram of the Study



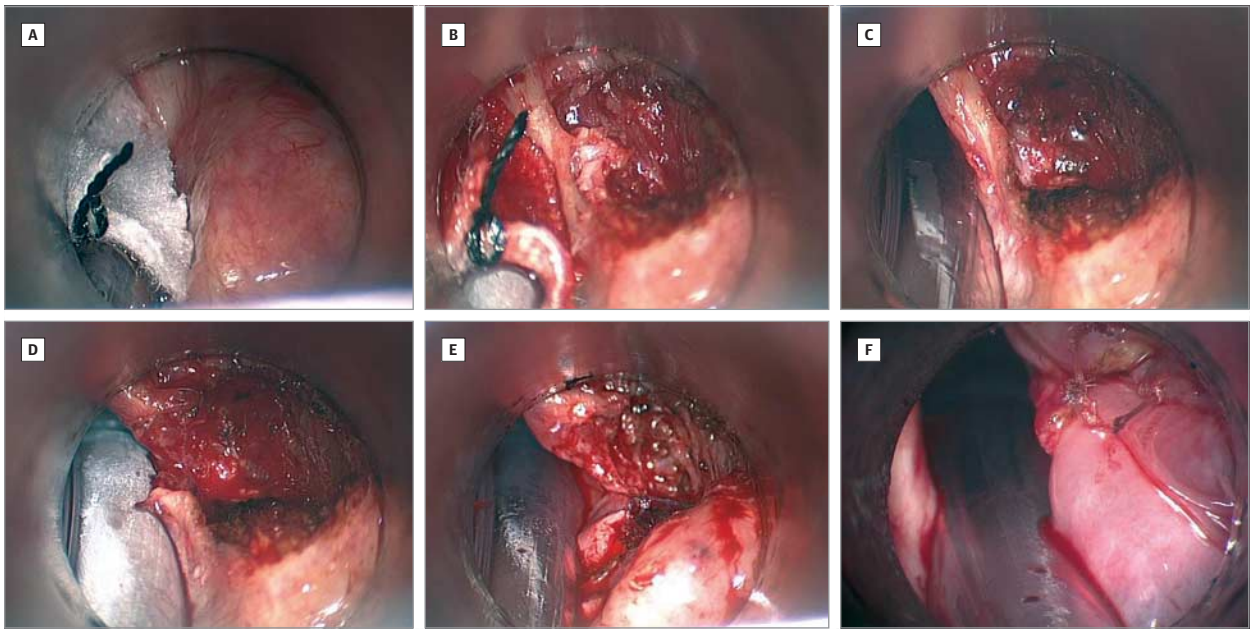
BVFP indicates bilateral abductor vocal fold paralysis.

Figure 2. Total Arytenoidectomy Technique



A, A surgical laryngoscope was placed right next to the right arytenoid to be removed. B, Anteriorly based triangular incision was marked with carbon dioxide laser spots on the right arytenoid. C, The right arytenoid cartilage was removed and cricoarytenoid joint surface became visible; mucosa medial to arytenoid was preserved to be used as a medially based advancement flap. D, Medially based advancement flap and membranous vocal fold were sutured posterolaterally.

Figure 3. Partial Arytenoidectomy Technique



A, A surgical laryngoscope was placed right next to the right arytenoid to be partially removed; intubation tube was covered with wet cottonoid against accidental laser shots. B, Soft tissue over the right arytenoid was removed by using a carbon dioxide laser, and cartilage of arytenoid became visible. C, Vocal process and anterior half of body of arytenoid was evaporated with a laser. Mucosa medial to arytenoid was preserved to be used as a medially based advancement flap. D, Preserved mucosa medial to arytenoid was cut right behind the membranous vocal fold, and medially based advancement flap is ready for suturing. E, Medially based mucosal advancement flap was sutured posterolaterally over the remnant body of arytenoid. F, Vocal fold lateralization was done with endoscopic microsuture by suturing the membranous vocal fold lateral to the remnant of body of arytenoid, thus covering all open wounds.

All operations were performed by the senior author (T.Y.), and other evaluations were performed by the other authors. The patients knew they would undergo arytenoidectomy but not the subtype. The evaluators were also not informed about the subtype of arytenoidectomy performed.

Preoperative, postoperative, and intraoperative evaluations included the following:

- Duration of each operation was recorded in minutes.
- Thirty-Item Voice Handicap Index (VHI-30) including physical, functional, emotional, and total scores was determined.
- Aerodynamic analysis using Aerophone II Model 6800 included maximum phonation time, mean airflow rate, mean resistance, mean power, mean efficiency, and mean pressure.
- Acoustic analysis with the vowel /a/ at comfortable pitch and loudness using CSL Model 4300B (Kay Elemetrics) included fundamental frequency, absolute jitter, shimmer percentage, and noise to harmonic ratio.
- Subjective comparison of preoperative and postoperative voice by phoniatrician on a scale of −2 to +2, where −2 indicates significantly worse; −1, somewhat worse; 0, no change; +1, somewhat better; and +2, significantly better.
- Speech intensity on the vowel /a/ was measured.
- Breathing ability was evaluated on a scale of −2 to +2, where −2 indicates, significantly worse; −1, somewhat worse; 0, no change; +1, somewhat better; and +2, significantly better.
- Functional Outcome Swallowing Scale (FOSS): 0 to 5, where 0 indicates normal function and asymptomatic; 1, normal function with episodic or daily symptoms of dysphagia; 2, compensated abnormal function manifested by significant dietary modifications or prolonged mealtime (without weight loss or aspiration); 3, decompensated abnormal function with weight loss of less than 10% of body weight over 6 months due to dysphagia or daily cough, gagging, or aspiration during meals; 4, severely decompensated abnormal function with weight loss of more than 10% of body weight over 6 months due to dysphagia, or severe aspiration with bronchopulmonary complications, or nonoral feeding for most nutrition; and 5, nonoral feeding for all nutrition.[3]

Preoperative examinations were repeated 1 year after surgery. All evaluations were performed by voice therapists in our department and recorded on patients' medical charts.

Results

Comparisons of preoperative and postoperative VHI-30 results, aerodynamic measures, and acoustic analysis with the vowel /a/ for the partial and total arytenoidectomy groups are given in **Table 1**. A subjective comparison by phoniatrician of preoperative and postoperative voice of the partial and total arytenoidectomy groups is given in **Table 2**. Preoperative and postoperative speech intensity on the vowel /a/ for the partial and total arytenoidectomy groups is given in **Table 3**. Postoperative breathing ability of the partial and total arytenoidectomy groups is given in **Table 4**. A comparison of preoperative and postoperative FOSS for the partial and total arytenoidectomy groups is given in **Table 5**. There were no statistically significant differences for these measures ($P > .05$).

The median duration of partial and total arytenoidectomy operations were 59 and 49 minutes, respectively. This difference was statistically significant (Z score, 2.06; Mann-Whitney test, $P = .04$).

Discussion

Of the endoscopic techniques for arytenoidectomy, the most widely accepted is probably the technique described by Thornell.[4] It is carried out under a temporary tracheostomy. A small mucosal incision over the arytenoid area extending into the aryepiglottic fold allows for the preparation and extraction of the cartilage. Occasional bleeding is controlled with electrocautery, which again leads to retraction of the structures laterally in the process of maturing of the fibrous tissue. An acrylic obturator is inserted between the cords and removed 3 to 4 weeks postoperatively.[4]

An important point in all glottis-enlarging interventions is the determination of the optimal amount of tissue to be resected to achieve sufficient airway lumen and acceptable voicing. The results vary from patient to patient. Furthermore, the intraoperative findings do not accurately predict the mature postoperative status. The arytenoid is seen as a key structure, the removal of which provides enlargement of the posterior "respiratory" glottis.[5]

Arytenoidectomy with removal of the covering mucosa for glottic airway restoration is very susceptible to granuloma and scar formation. A raw surface in the larynx may cause excessive scar formation and scar contracture, which inevitably leads to a renarrowing of the airway because the defect is not well covered with mucosa. These phenomena may occur after the surgery.[5]

Kleinsasser and Nolte[6] underlined an important enhancement to his technique of arytenoidectomy by the division of the conus elasticus in cranial-caudal plane. This reduced the tension of the subglottic sphincter, adding to a greater enlargement of the glottis.

Remacle et al[7] proposed the so-called subtotal arytenoidectomy by resecting the body of the arytenoid and preserving only a small posterior shell, which should protect the airway from aspiration. However, the enlargement of the glottis chink may be only moderate unless additional submucosal cordectomy and lateralization are performed. Plouin-Gaudon et al[8] gave their long-term results on subtotal arytenoidectomy, indicating that the advantage of subtotal arytenoidectomy lied in the fact that it maintained a certain degree of rigidity along the posterior limit of the arytenoid frame, preventing inward collapse of the mucosa and thus lowering the risk of aspiration.

Aiming at maximal preservation of the phonatory structures, Crumley[9] introduced the endoscopic laser medial arytenoidectomy, where a resection of the medial part of the arytenoid body is performed under preservation of its complete lateral, posterior, and inferior aspects and the vocal process. Medial arytenoidectomy enlarged posterior airway 1 to 2 mm by creating a concavity along the glottic edge of body of arytenoid cartilage and preserved voice by preserving membranous vocal fold. It had a minimal negative effect on phonation. Bosley et al[10] determined that medial arytenoidectomy had the ability to enlarge laryngeal airway in BVFP and that it had minimal

Table 1. Comparison of Preoperative and Postoperative VHI-30 Results, Aerodynamic Measures, and Acoustic Analysis With the Vowel /a/ for the Partial and Total Arytenoidectomy Groups

	Partial Arytenoidectomy Group[a]	Total Arytenoidectomy Group[a]	*Z* Score	*P* Value[b]
VHI-30 Result				
Preoperative				
Physical	10.0	11.0	−0.8	.42
Functional	6.0	6.0	−0.04	.97
Emotional	5.5	5.5	−0.04	.97
Total[c]	22.0	23.0	−0.49	.62
Postoperative				
Physical	16.5	16.5	−0.23	.82
Functional	14.0	16.0	−0.99	.32
Emotional	14.0	14.5	−1.07	.29
Total[c]	42.0	50.5	−1.03	.31
Aerodynamic Measure				
Preoperative				
Maximum phonation time, s	12	10	0.7	.48
Mean airflow rate, L/s	0.20	0.23	−0.5	.62
Mean resistance, cm H_2O/L/s	112	108	0.9	.36
Mean power, W	0.07	0.08	−0.3	.76
Mean efficiency, ppm	60	55	1.2	.23
Mean pressure, cm H_2O	4.9	4.7	1.3	.19
Postoperative				
Maximum phonation time, s	9	8	1.1	.27
Mean airflow rate, L/s	0.22	0.25	−0.9	.36
Mean resistance, cm H_2O/L/s	62	57	1.5	.13
Mean power, W	0.05	0.06	−0.2	.84
Mean efficiency, ppm	52	48	1.0	.31
Mean pressure, cm H_2O	3.71	3.55	0.7	.48
Acoustic Analysis With the Vowel /a/				
Preoperative				
F0, Hz	205	211	−1.3	.19
Jita, μs	104	95	1.6	.10
Shim, %	6.62	7.02	−0.9	.36
NHR	0.08	0.07	0.3	.76
Postoperative				
F0, Hz	214	224	−0.4	.68
Jita, μs	212	220	−0.8	.42
Shim, %	9.75	9.99	−1.6	.10
NHR	0.14	0.15	−1.1	.27

Abbreviations: F0, fundamental frequency; Jita, absolute jitter; NHR, noise to harmonic ratio; Shim, shimmer percentage; VHI-30, 30-Item Voice Handicap Index; μs, microseconds.

[a] The numbers in research group columns are median values.

[b] Mann-Whitney test.

[c] Median values may not add up to total number.

negative effect on phonatory and swallowing function. Young and Rosen[11] reviewed the literature and commented that medial arytenoidectomy continued to seek improvement in dyspnea symptoms with minimal decline in voice and/or swallowing function and high decannulation rates and that postoperative dysphagia appeared to be less commonly observed.

Sapundzhiev et al[5] believe that the most serious complications of the endolaryngeal arytenoidectomy include the creation of scar formation resulting in a posterior glottic stenosis and aspiration caused by the lowering of the aryepiglottic fold after arytenoidectomy. They further indicate that both complications mainly result from an approach too far posteriorly, ie, the deepithelialization of the posterior glottis wall or complete arytenoidectomy with lowering of the aryepiglottic fold, respectively. They advise that the posterior glottic wall should be carefully respected and complete arytenoidectomy should be performed only using techniques that preserve the medial mucous membrane part of the arytenoid cartilage.[5] Furthermore, Hillel et al[12] indicate that vocal fold lateralization after total arytenoidectomy results in an unsatisfactory voice. We

Table 2. Subjective Comparison of Preoperative and Postoperative Voice by a Phoniatrician[a]

Voice	Patients, No.	
	Partial Arytenoidectomy Group	Total Arytenoidectomy Group
Significantly worse	1	2
Somewhat worse	6	6
No change	3	2

[a] χ^2 Test, 0.53; $P = .77$.

Table 3. Preoperative and Postoperative Speech Intensity on the Vowel /a/ for the Partial and Total Arytenoidectomy Groups

Speech Intensity on the Vowel /a/	Partial Arytenoidectomy Group, dB[a]	Total Arytenoidectomy Group, dB[a]	Z Score	*P* Value[b]
Preoperative	65	65	0.6	.54
Postoperative	60	61	0.9	.36

[a] The numbers in research group columns are median values.

[b] Mann-Whitney test.

Table 4. Postoperative Breathing Ability of the Partial and Total Arytenoidectomy Groups[a]

Breathing Ability	Patients, No.	
	Partial Arytenoidectomy Group	Total Arytenoidectomy Group
−2 (Significantly worse)	0	0
−1 (Somewhat worse)	0	0
0 (No change)	0	0
+1 (Somewhat better)	2	1
+2 (Significantly better)	8	9

[a] χ^2 Test, 0.39; $P = .53$.

Table 5. Comparison of Preoperative and Postoperative FOSS for the Partial and Total Arytenoidectomy Groups[a]

FOSS	Patients, No.	
	Partial Arytenoidectomy Group	Total Arytenoidectomy Group
Preoperative		
Episodic (1[b])	9	8
Compensated (2[c])	1	2
Postoperative		
Episodic (1[b])	9	8
Compensated (2[c])	1	2

Abbreviation: FOSS, Functional Outcome Swallowing Scale.

[a] χ^2 Test, 0.39; $P = .53$.

[b] 1 = Normal function with episodic or daily symptoms of dysphagia.

[c] 2 = Compensated abnormal function manifested by significant dietary modifications or prolonged mealtime (without weight loss or aspiration).

must point out that these assumptions about aspiration and voice after total arytenoidectomy rely on their or others' beliefs rather than objective evidence.

Both partial and total arytenoidectomy provide comparable airway, voice, and deglutition. However, partial arytenoidectomy is a longer operation than total arytenoidectomy. In our small group of patients, both partial and total arytenoidectomy was highly successful in terminating airway obstruction of BVFP. Between the 2 groups, the results from the VHI-30, acoustic and aerodynamic analysis, subjective postoperative voice evaluation, postoperative voice intensity, postoperative breathing ability, and postoperative swallowing scale assessments were similar. Partial arytenoidectomy did not promise any advantage over total arytenoidectomy. In other words, total arytenoidectomy was not disadvantaged against the partial. However, partial arytenoidectomy took significantly longer operation time compared with total. Furthermore, a laser must be used for partial arytenoidectomy; however, total arytenoidectomy can also be performed with cold instruments without using a laser at all. Intraoperative bleeding is not a problem when you infiltrate operative field with 1:50 000 to 1:100 000 adrenaline solution before incising mucosa.

Preserving overlying healthy mucosa is very important for the success of arytenoidectomy, partial or total. Preserving mucosa means preserving sensation and less aspiration because the internal branch of the superior laryngeal nerve is functional in most of these patients. Burning mucosa and submucosal tissues with laser or electrocautery is not a good surgical technique because it will lead to uncontrolled scar tissue without sensation. Lack of sensation predisposes to aspiration and swallowing problems, and uncontrolled scar tissue may lead to stenosis of glottis and supraglottis with insufficient postoperative airway. Leaving the surgical area to secondary epithelialization predisposes to granulation tissue formation, which may lead to airway obstruction and predispose to laryngeal stenosis. The technique we described does not leave any open wound for secondary epithelialization by using medially based mucosal advancement flap and membranous vocal fold. That is why we did not observe any postoperative granulation tissue formation.

Preserving membranous vocal fold and suturing it posterolaterally toward the previous location of the muscular process of arytenoid cartilage lateralizes and tenses the vocal fold and closes de-epithelialized surgical area laterally, thus preserving the voice while also enlarging the airway and preventing granulation tissue formation. This can be seen in the VHI-30 and acoustic and aerodynamic analysis results. Most patients end up with a mild voice handicap, which we believe is acceptable. We do not remove any piece of true and false vocal fold, except mucosa of false vocal fold overlying arytenoid cartilage.

In the case of revision after unsuccessful glottis dilation procedure with inadequate airway, we may suture membranous vocal fold laterally, instead of posterolaterally, to gain more airway; however, in such a situation airway will be improved at the expense of loss of voice. This is practiced only after failed previous operations, not in primary cases.

Loss of arytenoid height is one disadvantage of total arytenoidectomy. This is preserved in case of partial arytenoidectomy. We believe that preserved mucosal sensation prevents free

flow of hypopharyngeal contents into laryngeal lumen after total arytenoidectomy. Another advantage of partial arytenoidectomy is that it provides a chance for revision with a high likelihood of success if the primary operation fails; in such a case one can easily perform total arytenoidectomy as a revision. However, after failed total arytenoidectomy, the revision operation becomes very difficult and less likely than the primary operation to be successful. Therefore, it may be a sound practice to perform partial arytenoidectomy initially for primary BVFP cases and reserve total arytenoidectomy for revision cases without fear of aspiration and phonation problems.

In conclusion, endoscopic total and partial arytenoidectomy both are still very successful static surgical options for BVFP. Their voice and deglutition results are similar and satisfactory. A laser is not a requirement for total arytenoidectomy but is needed for partial. Partial arytenoidectomy takes longer than total. They both provide comfortable airway, acceptable voice, and acceptable deglutition. It may be a sound practice to perform partial arytenoidectomy initially for primary BVFP cases and reserve total arytenoidectomy for revision cases without fear of aspiration and phonation problems.

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Study concept and design: Yılmaz.
Acquisition of data: Yılmaz, Süslü, Atay, Özer, Günaydın, Bajin.
Analysis and interpretation of data: Yılmaz, Atay, Özer, Günaydın.
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