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Systematic Review With or Without Meta-analysis

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Management of Bilateral Vocal Fold Paralysis: A Systematic Review

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Abstract

Objective. To review the current literature about epidemiology, etiologies and surgical management of bilateral vocal fold paralysis (BVFP).

Data Sources. PubMED, Scopus, and Cochrane Library.

Review Methods. A systematic review of the literature on epidemiology, etiologies, and management of adult patients with BVFP was conducted through preferred reporting items for systematic reviews and meta-analyses statements by 2 investigators.

Results. Of the 360 identified papers, 245 were screened, and of these 55 were considered for review. The majority (76.6%) of BVFP cases are iatrogenic. BVFP requires immediate tracheotomy in 36.2% of cases. Laterofixation of the vocal fold was described in 9 studies and is a cost-effective alternative procedure to tracheotomy while awaiting potential recovery. Unilateral and bilateral posterior transverse cordotomy outcomes were reported in 9 and 7 studies, respectively. Both approaches are associated with a 95.1% decannulation rate, adequate airway volume, but voice quality worsening. Unilateral/bilateral partial arytenoidectomy data were described in 4 studies, which reported lower decannulation rate (83%) and better voice quality outcome than cordotomy. Revision rates and complications vary across studies, with complications mainly involving edema, granuloma, fibrosis, and scarring. Selective posterior cricoarytenoid reinnervation is being performed by more surgeons and should be a promising addition to the BVFP surgical armamentarium.

Conclusion. Depending on techniques, the management of BVFP may be associated with several degrees of airway improvements while worsened or unchanged voice quality. The heterogeneity between studies, the lack of large-cohort controlled randomized studies and the confusion with posterior glottic stenosis limit the draw of clear conclusion about the superiority of some techniques over others.

Keywords

head neck surgery, immobility, laryngeal, larynx, nerve, otolaryngology, palsy, paresis, vocal fold paralysis, voice, reinnervation

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Bilateral vocal fold paralysis (BVFP) is a neurological condition associated with reduced or absent movement of both vocal folds. BVFP is related to processes affecting the neurological control of vocal fold movement, including neuropathies of the vagus nerve or the recurrent laryngeal nerve (RLN), neuromyopathies, or central neurologic problems.[1] The most frequent etiologies include iatrogenic injury, cancer, or neurological diseases.[2,3] The clinical presentation depends on the functional impairments (paralysis vs paresis) and the position of paralyzed vocal folds, which are in paramedian position in most cases.[4] The reduction of the glottal area results in inspiratory dyspnea and noisy breathing, while reduced vocal fold adduction can lead to dysphonia.[5] Some compromised airways require urgent intervention such as tracheotomy, while the long-term intervention depends on the degree of recovery of active vocal fold abduction. The primary objective of surgery for BVFP is to relieve the dyspnea while maintaining the voice quality as much as possible. A host of endoscopic procedures have been developed for patients with persistent paramedian BVFP and related dyspnea, including laterofixation, partial or total arytenoidectomy, posterior transverse cordotomy, or combined procedures.[5,6] While there is a fair amount of literature on the individual surgical techniques, few papers have attempted to provide an overview of the literature and compare the various techniques.[7] Such a review would be a valuable resource for laryngeal surgeons managing patients with BVFP.

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The objective of the present paper is to review the current literature about the epidemiology, etiologies and surgical management of BVFP in the adult population.

Methods

Search Strategy

A PubMed, Scopus, and Cochrane Library database research was conducted by 2 investigators (S.H. and J.R.L.) for relevant peer-reviewed publications in the English language related to epidemiology (incidence and prevalence), etiologies, and surgical management of BVFP. PubMed, Cochrane Library, and Scopus were used as search database. The following keywords were used "vocal cord," "vocal cord paralysis/epidemiology," "vocal cord paralysis/etiology," "vocal cord paralysis/surgery," "bilateral," "management," and "procedure," to identify clinical prospective/retrospective studies, reviews and meta-analyses. Case reports were excluded. Studies were considered if they had database abstracts, available full-texts, or titles containing the search terms. Results of the search strategy were reviewed for relevance and the reference lists of these articles were examined for additional pertinent studies.

Study Selection and Data Synthesis

The criteria for consideration of study inclusion for the systematic review were based on the population, intervention, comparison, outcome, timing, and setting framework. The review was conducted regarding the preferred reporting items for systematic reviews and meta-analyses (PRISMA) checklist for systematic reviews.[8] For each included study, 2 authors independently reviewed and extracted the data. Any discrepancies in synthesized data were discussed and resolved by the remaining co-authors.

Types of Studies

Papers were selected for inclusion in the final review if they reported data on epidemiology, etiologies, or surgical treatment of BVFP. Studies including data from combined surgical approaches (eg, association of posterior transverse cordotomy and arytenoidectomy) were excluded.

Populations, Inclusion/exclusion Criteria

Authors should report inclusion/exclusion criteria, the definition of BVFP, diagnostic approach, management, and therapeutic outcomes. Studies including patients with unspecified laryngeal immobility, or posterior glottic stenosis were excluded. The authors needed to support the BVFP diagnostic through the clinical history of the patient (eg, immediate postsurgical paralysis) and/or the absence of clinical, electromyography (EMG), or endoscopic findings of posterior glottic stenosis. The positions of the vocal folds were defined as median, intermediate, or lateral. Paresis was diagnosed if movement was sluggish, while paralysis was diagnosed if no volitional movement was observed.

Outcomes

The following outcomes were reviewed: study design; number of patients; age; gender; etiologies; baseline tracheotomy (prior to definitive surgical procedure); surgical procedures; number of procedures per patients; postsurgical procedure decannulation rate; voice, swallowing, or airway outcomes; complications; and revision features.

Intervention and Comparison

The following surgical procedures were considered: tracheotomy; unilateral or bilateral laterofixation of the vocal folds; unilateral or bilateral posterior transverse cordotomy; unilateral or bilateral partial and total arytenoidectomy; selective laryngeal reinnervation; and laryngeal pacing. Studies including both posterior glottic stenosis and BVCP were excluded. Heterogeneity among included articles in decannulation, postoperative functional, and surgical revision outcomes precluded statistically pooling the data into a formal meta-analysis, thereby limiting the analysis to a qualitative rather than quantitative summary of the available information.

Timing and Setting

There were no criteria for specific stage or timing in the "disease process" of the study population.

Results

Article selection is summarized in the PRISMA flow chart (**Figure 1**). Of the 360 identified papers, 245 were screened, and of these 55 were considered for review. Among them, 9 studies were dedicated to laterofixation of the vocal folds. Unilateral and bilateral posterior transverse cordotomy outcomes were reported in 9 and 7 studies, respectively. Unilateral/bilateral partial arytenoidectomy data were described in 4 studies, while 6 studies investigating total arytenoidectomy were included. Epidemiology, etiologies, and treatment outcomes were systematically described. The treatment findings were subdivided into reversible treatments for acute airway distress (tracheotomy and laterofixation of the vocal folds); botulinum toxin injections; and permanent surgery (unilateral or bilateral posterior transverse cordotomies, partial and total arytenoidectomies, laryngeal pacing and reinnervation).

Epidemiology

The prevalence and incidence of BVFP remain uninvestigated in the general adult population.[9] As the primary etiology of BVFP is postsurgical nerve injuries, a few population-based cohort studies reported epidemiological findings in specific populations, such as patients with primary thyroid cancer,[10] thyroidectomy,[11,12] or esophagectomy.[13] A large database analysis from 14,934 patients suggested an incidence of BVFP in 0.2% to 0.6% of thyroidectomy cases.[12] Francis

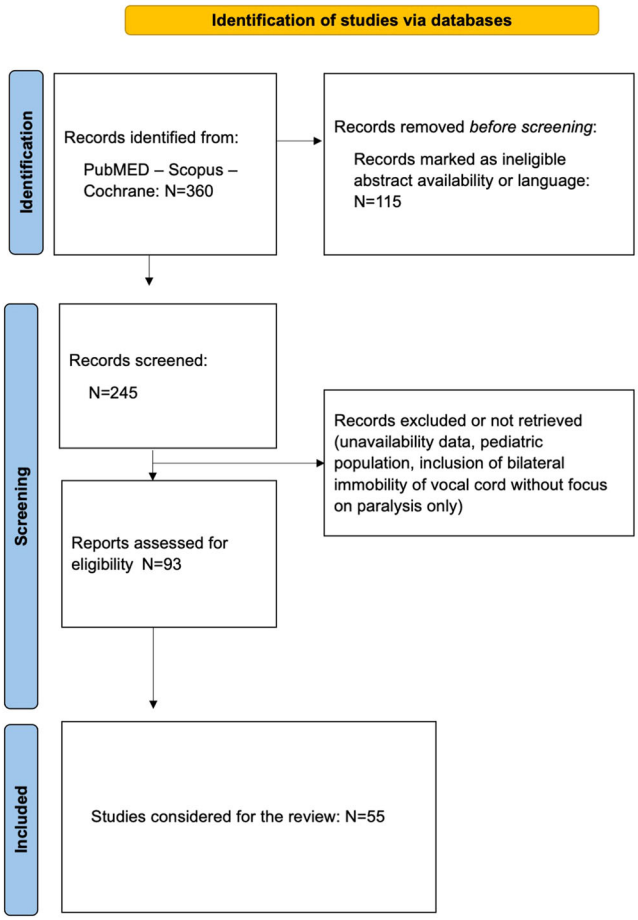

Figure 1. Preferred reporting items for systematic reviews and meta-analyses flow chart.

et al reviewed data from 5670 Medicare patients and reported that 1.3% of total thyroidectomies for well-differentiated thyroid carcinoma were complicated by BVFP with 28% of cases requiring surgical management.[10] The median diagnostic time was 6.7 months postoperatively with a 9% annual reduction in rate of BVFP over the past 2 decades. The authors showed that advanced age, non-Caucasian race, particular histologic types, and advanced stage increased the risk of bilateral paralysis.[10] The middle age, female sex, and an increased length of hospital stay were additional factors associated with an increased incidence of BVFP according to a recent Taiwanese study.[14] The potential influence of female sex was supported by Aspinall et al who reported a slight predominance of idiopathic causes in females.[15] However, the sex susceptibility remains controversial because thyroid diseases occur more frequently in females[12] and, consequently, females are more at risk to postoperative complications. The lack of neuromonitoring during surgery increases the incidence of BVFP.[16] Indeed, Goretzki et al reported in a retrospective chart review of over 1300 total thyroidectomies that the 17% rate of BVFP decreased to 0% rate when surgeons proceeded to the second lobectomy with a known or unrecognized nerve injury on the first side.[16] Among patients who underwent transthoracic and thoracoscopic esophagectomy, the BVFP prevalence is around 33% in a cohort study including 206 patients.[17]

Table 1. Etiology of Bilateral Vocal Cord Paralysis

Etiology	N (1182)	Percentage
Postsurgery	905	76.6
Thyroidectomy	879	97.1
Esophagectomy	13	1.4
Brain/skull base surgery	6	0.7
Tracheal/chest surgery	5	0.6
Bilateral glomus surgery	1	0.1
Thymic surgery	1	0.1
Idiopathic	82	6.9
Trauma	36	3.0
Neurological diseases	29	2.5
Unspecified	19	65.5
Neuromyopathies	2	6.9
Stroke	2	6.9
Guillain-Barré	2	6.9
Neurofibromatosis	1	3.4
Brain metastases	1	3.4
Parkinson	1	3.4
Bulbar disease	1	3.4
Cancers	19	1.6
Primary thyroid cancer	13	68.4
Laryngeal cancer	3	15.7
Lung cancer	1	5.3
Esophageal cancer	1	5.3
Neck metastasis	1	5.3
Congenital	14	1.2
Viral	4	0.3
Strangulation	4	0.3
Tuberculosis	2	0.2
Granulomatosis with polyangitis	1	0.1

Abbreviation: N = number.

Etiologies

Etiologies of BVCP were available in 36 papers (**Table 1**).[18-54] Surgical procedures were known for a long-time as responsible for most of the cases of BVFP. The data of studies were pooled to highlight the main etiologies of BVFP (**Table 1**).[18-54] Surgery (76.6%), idiopathic (6.9%), traumas (3.0%), and neurological diseases (2.5%) are the most common causes of BVFP. The surgical procedures associated with an increased risk of BVFP include thyroidectomy (97.1%),[18-25,27,28,31-54] esophagectomy (1.4%),[18,25,27] brain or skull base surgeries (0.7%),[28,31] tracheal or chest surgeries (0.6%),[25,48] bilateral glomus resection (0.1%),[52] and thymectomy (0.1%).[36] In most studies, authors did not specify the neurological conditions associated with BVFP (65.5%),[20,21,28] whereas others identified neuromyopathies (6.9%),[47] Guillain-Barré (6.9%),[22,42] stroke (6.9%),[40]

Parkinson disease (3.4%),[32] ataxia (3.4%),[48] bulbar disease (3.4%),[23] brain metastases (3.4%),[18] and neurofibromatosis (3.4%),[48] as potentially responsible of BVFP. Chest and head and neck cancers that may lead to BVFP are related to thyroid (68.4%),[18,22] larynx (15.7%),[18] lung (5.3%),[27] esophagus (5.3%),[40] or may consist of bilateral neck metastases (5.3%).[22] The other etiologies of BVFP are congenital (1.2%),[22,27,32] infectious (postviral,[19,25] or tuberculosis[27]), ischemic (strangulation, 0.3%),[19,24] or inflammatory (Wegener).[32] Radiation[28,33] and prolonged intubation[24,25,32,38] were suggested as potential etiologies of BVFP but authors included patients with bilateral vocal fold immobility, which may include posterior glottic stenoses. Similarly, others only focused on patients with only 1 possible cause of BVFP, for example, esophagectomy,[13] or thyroidectomy,[11,55-57] and, therefore, were not included in the assessment of the prevalence of BVFP etiologies.

Reversible Treatments for Acute Airway Distress

The occurrence of BVFP often results in acute airway distress necessitating urgent airway intervention. The dyspnea concerns the majority of patients with BVFP according to the 4 times greater fibers of adductor muscle compared to abductor muscle fibers, which explains the paramedian position of both paralyzed vocal cords.[58] From a medical standpoint, oxygen therapy, the use of Heliox, and the administration of intravenous and aerosol corticosteroids consist of the emergent steps to reduce dyspnea.[57,59] Surgically, tracheotomy and laterofixation of the vocal fold are reversible surgical procedures to address acute airway distress due to BVFP.

Tracheotomy

Tracheotomy has long-time been the preferred approach to restore the airway while maintaining the structural integrity of the glottic larynx. Tracheotomy is a rapid and effective procedure that does not require laryngological skills. This is particularly important because thyroid surgery is commonly performed by nonhead and neck surgeons in many world regions (eg, endocrine, digestive, or thoracic surgeons), who are not familiar with endoscopic laryngeal procedures.[60] According to studies reviewed, tracheotomy is required in 36.2% of cases (**Table 2**). Decannulation is achieved in 20% to 100% of cases depending on the surgical procedure (**Table 2**).[11,19,58] However, tracheotomy is associated with decreased quality of life, psychological and social problems, and requires continual postoperative care.[61-63] Currently, tracheotomy may be considered as an emergent surgical procedure for patients with severe dyspnea related to BVFP while awaiting recovery of movements of 1 or both vocal folds, which can take as long as 6 to 9 months postinjury.[11] Since the development of endoscopic laryngeal procedures since the beginning of the 20th century, the laterofixation of the vocal fold was proposed as an alternative procedure to tracheotomy[64] and has gained in popularity over the past 3 decades.

Laterofixation of the Vocal Cord

The laterofixation of the vocal fold consists of the laterofixation of 1 vocal fold or vocal process of arytenoid through external or endoscopic surgical approach for several months (**Figure 2**). The feasibility, airway, and voice quality outcomes, complications, and revisions of laterofixation were reported in 9 studies (**Table 2**).[11,18-23,65,66] The decannulation rate ranges from 95% to 100% (mean: 97.0%) in studies with a 2-to-60-month follow-up period. Laterofixation is associated with adequate postoperative airway volume measurements, including forced inspiratory volume,[65] forced expiratory volume 1 s (FEV1),[11,22] and peak expiratory flow (PEF) rate,[11,22] and endoscopic glottic findings.[20,23] The complications of laterofixation include aspiration,[21,65] edema of arytenoid and vocal cord,[18,23,65,66] posterior glottic stenosis,[19] lateral migration of suture,[20] granuloma,[20] airway obstruction related to fibrin,[18] or hematoma.[23] The revision rate ranged from 4.0% to 7.7%.[19,20,65,66] The 3 most prevalent reported complications consisted of laterofixation rupture/releasing fixed fold (7.7%-36.0%), postoperative laryngeal edema (7.7%-17.1%), and aspiration (4.0%-9.1%; **Table 3**). To date, laterofixation of the vocal fold may be considered as an alternative and cost-effective[67] endoscopic surgical procedure to tracheotomy in patients with severe dyspnea related to BVFP.[18,20]

Botulinum Toxin Injection

Nonsurgical treatments of BVCP included voice therapy and botulinum toxin injection.[61] Voice therapy is mainly indicated for patients with dysphonia related to BVCP. Botulinum toxin injections are commonly performed in cases of aberrant reinnervation of the adductor muscles by inspiratory motoneurones to improve the glottic opening.[68,69] To date, there are 2 case reports or small case series of patients treated with botulinum toxin injection.[68,69] According to the case series of Ekbom et al, the use of botulinum toxin type A in patients with respiratory compromise due to bilateral vocal fold motion impairment may result in a long-term patient-reported symptom improvement in most cases after an average of 9 injections over 10-year period of study.[68]

Permanent Surgeries

If recovery does not occur and the patient remains symptomatic, there are several endoscopic surgical options to increase the glottic aperture. Because it remains complicated to draw conclusion from retrospective nonrandomized studies in which authors compared several procedures, we mainly reported findings of single-surgical procedure studies. The main permanent procedures include unilateral or bilateral posterior transverse cordotomy, unilateral or bilateral partial or total arytenoidectomy, or a combination of several approaches (**Figure 2**). Studies investigating outcomes, complications, and revisions of single procedures are

Table 2. Summary of Studies as Grouped by Surgical Approach

Type of surgery	Design	N	M/F	Age (A/M)	Tracheot.	Deca.	Timing	Follow-up	Outcomes	Effective rate
Laterofixation										
Geterud et al[21]	Retrospective	11	4/7	65	NP	NP	NP	60 mo	Airway volume	Pre = postsurgery
Rovo et al[65]	Retrospective	15	1/14	33-73	2/15	2/2	6 mo[b]	17 mo	Airway volume	Post > presurgery
Rovo et al[19]	Prospective	25	5/20	33-81	5/25	5/5	1-6 mo	25 mo	Dyspnea	96%
Leitersdorfer et al[11]	Retrospective	92	18/74	56	NP	NP	NP	2-6 mo	Airway volume	Post > preurgery
Hyodo et al[22]	Prospective	11	3/8	11	6/11	6/6	NP	2 mo	Airway volume	91%, post > presurgery
Ezzat et al[20]	Prospective	21	8/13	36	21/21	20/21	>1 wk	6 mo	Endoscopic findings	76%
Oysu et al[66]	Retrospective	13	0/13	52	0/13	NP	8 mo[b]	24 mo	Dyspnea	92%
Korkmaz et al[23]	Retrospective	47	3/44	NP	NP	NP	NP	19 mo	Dyspnea	94%
Wiegand et al[18]	Retrospective	35	13/22	64	3/35	3/3	>1 wk	NP	Decannulation	100%
Posterior unilateral cordotomy										
Laccourreye et al[40]	Retrospective	25	6/19	63	NP	NP	NP	5 years	Endoscopic findings	68%
Segas et al[45]	Retrospective	20	8/12	50	12/20	18/20	>3 mo	5 mo	Dyspnea	90%
Yagudin et al[46]	Prospective	21	0/21	56	21/21	21/21	>12 mo	3 mo	Airway volume	Post > presurgery
Oysu et al[42]	Retrospective	11	1/10	NP	2/11	2/2	>6 mo	6-15 mo	Exercise tolerance	Post > presurgery
Ozdemir et al[34]	Retrospective	66	8/58	48	7/66	NP	NP	40 mo	Airway restoration	88%
Khalil and Tawab[39]	Prospective	18	8/10	47	NP	NP	6 mo[b]	12 mo	Airway volume	72%
Ozturk et al[43]	Controlled	30	12/18	53	NP	NP	6 mo[a]	6 mo	Airway volume	Post > presurgery
Mohamed et al[41]	RCT	20	4/16	50	2/20	NP	12 mo[b]	12 mo	Dyspnea score	Post > presurgery
Rashid et al[44]	Retrospective	34	10/24	39	NP	NP	6 mo[b]	6 wk	Dyspnea	Post > presurgery
Posterior bilateral cordotomy										
Khalifa[74]	Prospective	22	8/14	41	18/22	12/22	>1 mo	1-2 mo	Decannulation	54%
Dursun and Gökcan[75]	Retrospective	22	8/14	45	6/22	NP	NP	12 mo	Dyspnea score	95%
Bajaj et al[36]	Retrospective	9	3/6	27-85	3/9	3/3	12 mo[a]	3-28 mo	Dyspnea and voice	100%-78%
Asik et al[35]	Prospective	11	2/9	46	0/11	0/0	48 mo[b]	2 mo	Airway volume	Post > presurgery
Basterra et al[37]	Retrospective	18	3/6	27-85	7/18	7/7	NP	2-5 years	Airway volume	74%-91%
Benninger et al[38]	Retrospective	15	4/11	57	3/15	2/3	NP	18 mo	Stridor	83%
Karkos et al[62]	Prospective	12	2/10	56	12/12	12/12	12 mo[b]	24 mo	Decannulation	100%
Partial uni/bilateral arytenoidectomy										
Crumley[47]	Retrospective	8	NP	NP	6/8	2/6	NP	6 mo	Exercice tolerance	100%
Gorphe et al[50]	Prospective	20	7/13	52	5/20	5/5	NP	3 mo	Dyspnea	100%
Yilmaz et al[53]	RCT	20	5/15	52	4/20	NP	NP	12 mo	Airway volume	Pre = postsurgery
Yilmaz[48]	Prospective	64	8/56	52	9/50	9/9	NP	12 mo	Airway restoration	88%
Total uni/bilateral arytenoidectomy										
Ossof et al[49]	Retrospective	11	1/10	59	6/11	10/11	NP	6-36 mo	Decannulation	91%
Szmeja and Wójtowicz[52]	Retrospective	30	NP	47	3/30	3/3	NP	NP	Dyspnea	100%
Li et al[63]	Prospective	9	0/9	53	NP	NP	NP	10 mo	Airway index	Post > presurgery
Misiolek et al[54]	Prospective	36	3/33	52	22/36	35/36	NP	1 mo	Airway volume	Post > presurgery
Yilmaz et al[5]	Retrospective	50	9/41	50	40/50	37/40	NP	1 mo	Dyspnea	Post > presurgery
Hu et al[51]	Retrospective	14	8/6	44	14/14	13/14	NP	6 mo	Decannulation	93%

Effective rate data are related to outcomes considered in the studies.

Abbreviations: A/M, average/mean; M/F, male/female; mo, month; NP, not provided; RCT, randomized controlled trial; wk, week.

[a]Median (for timing).

[b]Mean (for timing).

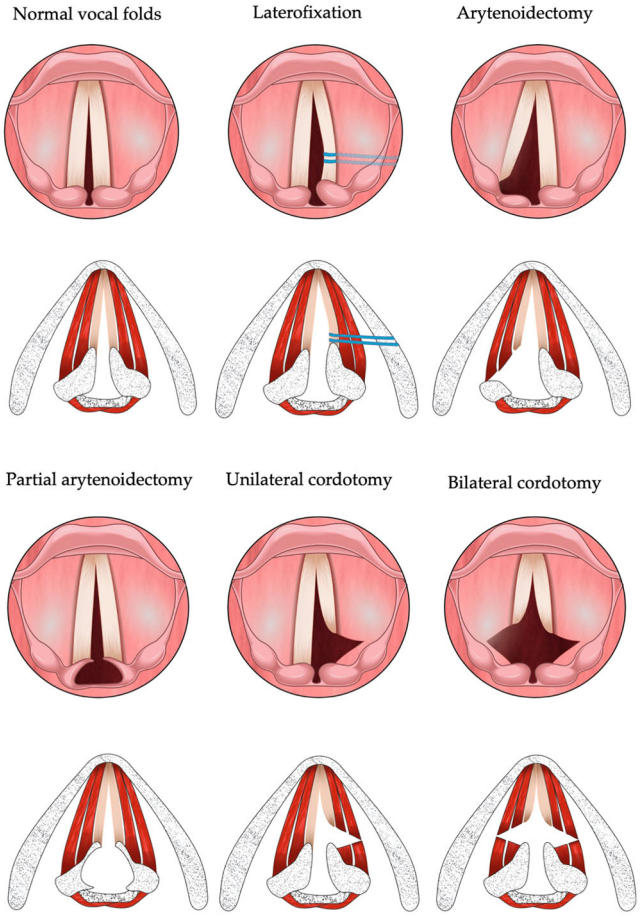

Figure 2. Surgical techniques.

summarized in **Tables 2** and **3**. Some studies reported the pre- to postoperative findings of patients treated with several procedures with,[32,70-72] or without,[29-31,33,54] comparison of outcome procedures.

Posterior Transverse Cordotomy

Posterior transverse cordotomy is one of the most common endoscopic procedures for BVFP. Outcomes were available in 16 studies.[35-46,60-62] The section of mucosa, ligament, and muscle of the vocal fold is carried out with cold instruments, CO_2 laser,[40,41,43] potassium-titanyl-phosphate laser,[45] diode laser,[73] coblation,[38] or radiofrequency monopolar.[42] The degree of posterior transverse cordotomy may vary based on the degree of muscle section.[31] The CO_2 laser-assisted cordotomy is the most used approach and did not report significant respiratory or voice outcome differences than the diathermy-assisted procedure in unilateral or bilateral posterior cordotomy.[43]

The decannulation rates of unilateral posterior cordotomy were reported in 3 studies and ranged from 90% to 100% (mean: 95.1%).[42,45,46] From a respiratory standpoint, unilateral posterior cordotomy is effective and improved subjective perceived respiratory/dyspnea score,[34,41-45] peak expiratory or inspiratory flow,[43,46] FEV1,[39,43] or maximum phonation time (MPT).[41] From a voice quality outcome, the approach may lead to worsening of perceptual voice quality,[44] while others did not find significant differences in pre- to postoperative voice handicap index (VHI),[34,42] and acoustic measurements.[41,43] The revision rates ranged from 0% to 45% (**Table 3**) and mainly concerned the management of postoperative dyspnea (laryngeal edema)[34,45] or granuloma.[34,45,46] Aspiration was reported in 5.6% of patients in the study of Khalil et al,[39] while others did not report aspiration cases.[40,42]

In case of insufficient benefit from unilateral posterior cordotomy, bilateral posterior cordotomy could be considered. Many authors proposed bilateral posterior cordotomy as the first procedure for patients with BVFP.[35-38,73-75] The mean decannulation rate of bilateral posterior transverse cordotomy was 76.6% (range: 0%-100%). The decannulation rate of bilateral cordotomy appears as lower than the mean decannulation rate of unilateral posterior cordotomy (95.1%) but the populations included in studies were substantially different. Thus, 31.9% of patients of unilateral cordotomy studies had baseline tracheotomy[34,41,42,45,46] versus 44.5% of individuals treated with bilateral cordotomy; whereas the severity of baseline airway outcomes was higher in bilateral versus unilateral cordotomy study populations (**Table 2**).[35-38,60-62] This difference may support the existence of different inclusion criteria, which makes the comparison difficult. Most authors reported that the patient-reported or physician perception of dyspnea,[35,36,38,61] MPT,[35,61] forced vital capacity,[35] PIF, FEV1,[35,37,61] VO_2 max,[35] improved postsurgery. The voice quality findings were more controversial with worsening (VHI,[35] grade, roughness, breathiness, asthenia, strain[35,37]) or unchanged[73] voice quality outcomes after surgery. A study reported improvements of VHI 516 days after the procedure.[38] The swallowing improved[73] or did not change from pre- to postsurgery.[37] The revision rate of bilateral posterior cordotomy ranged from 0% to 46.7% and was mostly related to the management of granuloma,[38] or fibrosis/scaring of the sectioned vocal cord.[74]

Total Arytenoidectomy

Total arytenoidectomy is an old external or endoscopic approach that gained in popularity with the development of CO_2 laser. The technique consists of the resection of 1 arytenoid cartilage to enlarge the glottic space (**Figure 2**). Outcomes were reported in 6 studies.[5,49,51,52,54,63] Some teams associated total arytenoidectomy with transverse cordotomy to improve the airway of patients with severe dyspnea.[29,31,76]

The decannulation rate is excellent (95.3%) in studies with a 1- to 10-month follow-up.[5,49,51,52,54,63] From a respiratory standpoint, the total arytenoidectomy was associated with significant improvements of patient-reported dyspnea,[52] FEV1,[54] vital capacity,[54] and PEF.[54] The voice quality outcomes of patients with total

Table 3. Complications

Type of surgery	Aspiration	Laryngeal Edema	Hematoma	Postop. Dyspnea	Fibrosis/ Scaring	PGS	Granuloma	Laterofixation Rupture	Suture Migration	Releasing Fixed cord	Surgical Revision
Laterofixation											
Geterud et al[21]	1/11										
Rovo et al[65]	1/15	3/15									1/15
Rovo et al[19]	1/25	4/25				1/25		3/25		9/25	1/25
Ezzat et al[20]							1/21		1/21		1/21
Oysu et al[66]		1/13						1/13			1/13
Korkmaz et al[23]		2/47	1/47								
Wiegand et al[18]		6/35		3/35						2/35	
Posterior unilateral cordotomy											
Laccourreye et al[40]	0/25	0/25	0/25	0/25			0/25	-	-	-	6/25
Segas et al[45]		8/20					7/20	-	-	-	9/20
Yagudin et al[46]							3/21	-	-	-	0/21
Oysu et al[42]	0/25	0/25	0/25	0/25			0/25	-	-	-	2/11
Ozdemir et al[34]		7/66		4/66			4/66	-	-	-	12/66
Khalil and Tawab[39]	1/18						3/18	-	-	-	
Ozturk et al[43]							6/30	-	-	-	0/30
Rashid et al[44]								-	-	-	6/34
Posterior bilateral cordotomy								-	-	-	
Khalifa[74]					4/22			-	-	-	4/22
Dursun and Gökcan[75]								-	-	-	
Bajaj et al[36]				1/9				-	-	-	0/9
Asik et al[35]	0/11	0/11	0/11	0/11			0/11	-	-	-	0/11
Basterra et al[37]								-	-	-	
Benninger et al[38]							4/15	-	-	-	7/15
Karkos et al[69]								-	-	-	
Partial uni/bilateral arytenoidectomy								-	-	-	
Crumley[47]	0/8	0/8	0/8	0/8			0/8	-	-	-	0/8
Gorphe et al[50]							1/20	-	-	-	5/20
Yilmaz et al[53]								-	-	-	
Yilmaz[48]								-	-	-	8/64
Total arytenoidectomy								-	-	-	
Ossof et al[49]						1/11		-	-	-	
Szmeja and Wójtowicz[52]					1/30			-	-	-	1/30
Li et al[70]	0/9	0/9	0/9	0/9			0/9	-	-	-	
Misiolek et al[54]								-	-	-	
Yilmaz[5]		1/50		1/50							3/50
Hu et al[51]					1/14			-	-	-	1/14

arytenoidectomy were reported in single-procedure study,[5] or in studies combining several approaches, for example, arytenoidectomy and posterior transverse cordotomy,[31] or arytenoidectomy with vocal cord lateralization.[32] Motta et al[31] reported worsening of MPT and acoustic measurements from pre- to postsurgery, while Anand et al[32] reported postoperative dysphonia in most patients. VHI-30, MPT, and acoustic parameters significantly worsened after total arytenoidectomy in the study of Yilmaz.[5]

The complications of total arytenoidectomy were poorly described in studies reporting data of total arytenoidectomy as single approach. Thus, laryngeal web,[49] scaring,[51] and laryngeal edema requiring tracheotomy,[5] were reported but in most studies, authors did not investigate the occurrence of aspiration and pneumonia. However, aspiration and related pneumonia appear to be prevalent, reaching 50% of cases according to some report.[71] The revision rate may reach 7% of cases, and is related to the development of scaring.[51,52]

The total arytenoidectomy is not a preferred procedure because of the poor postoperative voice quality outcomes and the risk of aspiration and related pneumonia, which are less prevalent in partial arytenoidectomy or posterior transverse cordotomy (0% vs 50%).[71] Total arytenoidectomy may be carried out for primary BVFP cases when partial arytenoidectomy or bilateral transverse cordotomy fail.

Partial Arytenoidectomy

Partial arytenoidectomy was developed by Crumley in 1993[47] and Remacle et al[77] in 1996. This approach consists of the unilateral or bilateral resection of the antero-median part of the arytenoid (vocal process) to enlarge the respiratory glottis, while preserving the phonatory glottis (**Figure 2**). Four studies were included in the present review.[47,48,50,53] The decannulation rate was 83% (range: 33%-100%)[47,48,50,53] at 3- to 12-month follow-up time. This technique is associated with significant improvements of respiratory outcomes (eg, exercice tolerance,[47] patient-reported dyspnea,[50] FEV1,[48] FIV,[48] airway volume,[53] airway resistance,[48] or physician-reported airway restoration[48]).

The voice quality is not worsened according to patients,[47,50] but conflicting data exist regarding the objective voice measurements. Yilmaz et al[48] reported worsening of VHI, MPT, voice intensity, and acoustic measurements at 12 months postsurgery, while Gorphe et al[50] did not show pre- to postsurgery significant differences in VHI and acoustic measurements. The complications of partial arytenoidectomy are rare or poorly reported, and mainly consist of postoperative granuloma.[50] The revision was needed in 14.1% for persistent dyspnea after surgery.[47,48,50] For these cases, framework laryngeal surgery may be discussed but patient comorbidities and the risk of complications (around 5%), such as fibrosis and posterior glottic stenosis, need to be considered in the benefit-risk ratio.[78,79]

The partial arytenoidectomy is a safe procedure according to the low rate of complication, the good postoperative airway outcomes, and the potential preservation of voice quality.[50,79] The advantage of partial arytenoidectomy over cordotomy is the preservation of the soft vocal cord tissue, which theoretically provides better voice quality outcomes.[79] However, to date, there is no randomized controlled trial comparing posterior transverse cordotomy versus partial arytenoidectomy in the management of definitive BVFP.

Laryngeal Pacing and Reinnervation

The ansa cervicalis-to-RLN, the hypoglossal-to-RLN, or the phrenic-to-RLN anastomoses are the main unilateral[80,81] or bilateral[82,83] laryngeal reinnervation approaches to restore the posterior cricoarytenoid muscle function and the vocal cord abduction.[80-83] Most case-series of laryngeal recurrent reinnervation for BVFP were reported in children.[82] In adults, the first case of phrenic-to-RLN anastomosis was reported in 1983 by Crumley who showed an improvement of glottic diameter but no active arytenoid movement.[83] Variations on the phrenic technique were described involving an extralaryngeal neurorrhaphy between the main trunk of the RLN and concomitant intralaryngeal transection of the adductor branches of the recurrent nerve.[84] Li et al reported that phrenic-based RLN reinnervation was associated with 93% recovery of vocal cord movement and 87% of decannulation.[85] In another case-series of 39 patients, this team used upper root of phrenic nerve and hypoglossal nerve branch to carry out the reinnervation.[86] Authors reported a recovery and decannulation rate of moderate-to-severe abduction in 89.7%. Patients reported a significant improvement of grade of dysphonia, VHI-10, acoustic measurements, and MPT at 12 months post-surgery, while most of the respiratory parameters returned to the normal reference level at 3 months postoperatively. Other reinnervation techniques were reported, including the use of the superior laryngeal nerve,[87] or the thyrohyoid nerve,[88] but the lack of cohort studies makes difficult the establishment of reliable conclusion.

As for laryngeal pacing, the usefulness of the functional electrical stimulation of paralyzed laryngeal muscles through a pacing device was investigated in few case-series.[89,90] Briefly, unilateral pacing appeared to be associated with significant respiratory outcomes without negative effect on voice quality. However, the lack of large cohort-controlled study limits the conclusion that can be drawn.

Discussion

The finding of the present systematic review highlighted that some surgical techniques were combined in numerous

studies but few authors compared the procedure outcomes. In 1994, Eckel et al reported the results of a prospective randomized controlled trial comparing posterior transverse cordotomy and arytenoidectomy in 18 and 10 patients with BVFP, respectively.[71] Results showed that plethysmography, flow volume, and spirometry outcomes were similarly improved from pre- to postsurgery in both groups.[71] Patients with arytenoidectomy reported a 50% rate of aspiration, while those with cordotomy did not report aspiration. Revision was needed in only 1/18 patients with cordotomy. Dispenza et al[55] observed decannulation rates of 60% and 96% in patients who underwent CO_2 arytenoidectomy versus CO_2 arytenoidectomy and posterior cordotomy, respectively.[55] Anand et al retrospectively compared posterior cordotomy, a modified cordoplasty approach, and combined arytenoidectomy and vocal cord lateralization in a cohort of 54 patients with BVFP.[32] Authors reported decannulation rates of 90%, 100%, and 77% in cordotomy, cordoplasty, and arytenoidectomy groups, respectively. The patient-reported dyspnea assessment was better in cordotomy and cordoplasty groups compared with aytenoidectomy group; while patients with posterior cordotomy reported higher prevalence of postoperative aspiration than others.[32] In a prospective randomized controlled study, Abdelhamid et al treated patients with laser cordotomy (N = 20) or concurrent laser cordotomy and laterofixation (N = 20).[72] The association of laser cordotomy and concurrent laterofixation was associated with significant better improvements of acoustic parameters and MPT, whereas there were no significant differences between groups for VHI and aspiration rates.[72]

To date, it is not straightforward to establish the superiority of 1 technique over others for many reasons. First, most studies are retrospective case-series with a low number of patients. Second, the inclusion and exclusion criteria may substantially vary from 1 study to another, some techniques being favored for patients with more severe dyspnea. The heterogeneity across studies also concerns the delay of procedure and the follow-up time. Note that the details about diagnostic approach for BVFP was not provided by authors in most studies because they based the diagnosis on the etiological findings. Thus, only a few authors used laryngeal EMG prior to surgery,[32,61,70,75,85] while many teams proposed surgery in the few weeks following the laryngeal paralysis without waiting for a potential recovery of vocal fold motion. The lack of description of diagnostic approach or use of EMG have limited us in the diagnosis approach analysis. The follow-up was shorter (<1 month) in some studies[44,54,55,72,74] to observe voice quality changes or delayed complications (eg, aspirations, posterior glottic stenosis, or scaring). Third, many authors do not differentiate BVFP from posterior glottic stenosis, both being grouped as laryngeal immobility in many studies in the literature. In the present paper, we only focused on BVFP but some studies with interesting findings were not reviewed because lack of details about the origin of vocal cord immobility. Finally, the pre- to postsurgery voice quality changes were reported without information about the potential postoperative speech therapy, which may significantly influence voice outcomes.

Conclusion

The management of BVFP may involve several surgical procedures that are associated with significant improvements of respiratory outcomes, adequate decannulation rate, and low complication rates. To date, the heterogeneity between studies and the lack of large cohort-controlled randomized studies limits the ability to draw reliable conclusions about the superiority of 1 technique over others in terms of surgical, voice, and respiratory outcomes, complication, and revision. Future studies are needed to improve the patient criteria selection for surgical procedures, and which procedures may be favored according to patient features.

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Author Contributions

Jérôme R. Lechien, design, acquisition of data, data analysis and interpretation, drafting, final approval, and accountability for the work; final approval of the version to be published; agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved; **Stephane Hans**, design, acquisition of data, data analysis and interpretation, drafting, final approval, and accountability for the work; final approval of the version to be published; agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved; **Ted Mau**, design, acquisition of data, data analysis and interpretation, drafting, final approval, and accountability for the work; final approval of the version to be published; agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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