Bilateral vocal fold immobility in a single tertiary hospital in northern Taiwan

A 23-year retrospective review

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Abstract
To determine the natural history of patient with bilateral vocal fold immobility (BVFI), and to identify the factors or predictors associated with the tracheostomy and duration of cannulation for those who require tracheostomy.

A retrospective review was carried out at a single tertiary referral center over a 23-year period of infants less than 1 year old who presented with BVFI. All information related to sex, etiology, gestational age at birth, vocal fold (VF) position at diagnosis, presence of concomitant airway disease, age at attainment of VF movement, age at decannulation, and current tracheostomy status were recorded to perform descriptive and comparative analyses.

Forty-one patients were enrolled, and the tracheostomy rate was 80.5% (33/41). Those with a median VF position had a higher rate of tracheostomy in comparison with those with a paramedian VF position (P = .003). Among patients who underwent tracheostomy, 77.4% (24/31) were eventually decannulated. The median duration of cannulation was 4.4 years (range: 0.8 – 10.7 years). Those who were found to have attainment of VF movement at less than 1-year-old had a shorter duration of cannulation than others (mean: 1.9 years vs 5.2 years, P < .001). The mortality rate of those patients who received tracheostomy was 9.7% (3/31).

Although a high tracheostomy rate was found in BVFI patients, most of them underwent decannulation. The earlier attainment of VF movement is achieved, the shorter duration of cannulation is required. This information is important for physicians while following up BVFI patients who have undergone tracheostomy.

Abbreviations: BVFI = bilateral vocal fold immobility, IQR = interquartile range, IRB = institutional review board, MCH = MacKay Children’s Hospital, UVFI = unilateral vocal fold immobility, VF = vocal fold, VFI = vocal fold immobility.

Keywords: bilateral vocal fold immobility, outcome, tracheostomy

1. Introduction
Vocal fold immobility (VFI) is a common cause of stridor in neonates. Daya et al reported 88 of 102 patients with VFI had been noted having stridor previously. It can be separated into unilateral VFI (UVFI) and bilateral VFI (BVFI). Jabbour et al have reported that cardiac surgery is the main cause of UVFI, while the cause of BVFI is usually idiopathic. Individuals with UVFI usually present with weak crying and choke while feeding, while those with BVFI mainly present with respiratory difficulties.

The goal of management for the patient with BVFI is to maintain the airway patency and avoid hypoxemia or hypercapnia. Tracheostomy had been the treatment of choice to achieve this goal for a long period. To those who had less severe symptoms, conservative approach such as oxygen supplement or non-invasive ventilation support may be adequate. Codotomy, arytenoidectomy or vocal fold lateralization is an alternative choice for those who have severe symptoms. However, these procedures may interfere with phonation.

The reported tracheostomy rate varies from 9% to 100% in patients with BVFI. Those who received tracheostomy were reported to have more subsequent hospitalization than children without tracheostomy. Previous study also showed that ongoing BVFI and neurogenic BVFI are related to decannulation failure. Since a prolonged cannulation status may cause both economic and psychosocial burdens to the caregiver as well as to those who require tracheostomy, the duration of cannulation is also a core issue when counseling affected families.

We conducted this study to investigate the natural course of patients with BVFI in Taiwan and to identify the factors associated with or predictors of the need for tracheostomy which had not been well identified. Additionally, the duration of cannulation for those who require tracheostomy, which has not been discussed previously, would be investigated in this study.

2. Methods
A retrospective chart review was conducted at MacKay Children’s Hospital (MCH), a tertiary hospital in Taipei, Taiwan, between January 1, 1994, and December 31, 2016. The study
was approved by the institutional review board of MacKay Memorial Hospital (IRB approval number: 17MMHIS084e). All data related to the patients were fully anonymized, and the informed consents were not required.

All patients younger than 1 year old with a diagnosis of BVFI, which were made via awake flexible laryngoscopy by the attending pediatric otolaryngologist, were enrolled. All information related to sex, etiology, gestational age at birth, prior intubation, gastroesophageal reflux disease, vocal fold position at diagnosis, presence of concomitant airway disease, age at attainment of vocal fold movement, age at decannulation, and current tracheostomy status were recorded. Factors related to the necessity of tracheostomy and subsequent decannulation were explored.

In our institution, patients suffering from respiratory distress were evaluated with a standardized protocol (Fig. 1). Patients who had BVFI and met one of the following criteria would be considered to undergo tracheostomy:

1. Severe airway obstruction necessitating endotracheal intubation to keep airway patency and failure to extubate,
2. Presence of severe complications related to vocal fold immobility and chronic respiratory insufficiency such as failure to thrive or recurrent aspiration pneumonia.

![Figure 1. Algorithm for managing patients possibly affected by BVFI.](image-url)
The rigid bronchoscopy was performed in the operation room under general anesthesia for all patients before performing tracheostomy. Checking for other airway abnormalities such as subglottic stenosis, passive mobility and fixation of cricoarytenoid joint were administrated while performing rigid bronchoscopy. The follow-up flexible laryngoscopies were performed in clinic every three months regularly, and additional laryngoscopies would be performed only when the patient suffered unexplained deterioration of respiratory condition.

The definition of vocal fold position was based on the angle between the true vocal folds. Median, paramedian and lateral vocal fold position were defined while the angle was 0 degrees, 0 to 30 degrees and more than 30 degrees. We used the same classification system as previous study to determine the etiology of BVFI. Neurogenic BVFI was defined as a BVFI diagnosis in the setting of a neurologic disease known to cause BVFI. Idiopathic BVFI was diagnosed when no contributor that could have caused BVFI was identified. The definition of the age at attainment of vocal fold movement was determined by the time at which movement of the vocal fold was detected by laryngoscopy. It did not mean complete recovery, which was identified and recorded via follow-up laryngoscopy.

2.1. Tracheostomy

The procedure was performed with the patient placed supine position and the neck extended. A 1-cm vertical incision was made between the cricoid cartilage and suprasternal notch. The strap muscles were separated and retracted laterally, exposing the thyroid isthmus. The thyroid gland was split with midline isthmussectomy, and the pretracheal fascia was dissected. Two 4–0 nylon stay suture of the trachea were made at the 2nd tracheal ring and beside the vertical tracheal incision wound. An adequate size of pediatric Shiley tracheal tube was inserted into the incisional opening of the trachea, and the tracheal tube was tied safely on the neck. The skin was approximated with 4-0 nylon suture.

2.2. Statistical analysis

All statistical analyses were performed using SPSS 23.0. Statistical significance was defined as P < 0.05. All P values in this analysis were of the 2-sided type. Categorical data were analyzed using the standard chi-square test and Fisher exact test. Continuous data were analyzed using the independent t test for between-group comparisons, where appropriate. Multivariate analyses were performed using the logistic regression model to identify the factors associated with or predictors of the need for tracheostomy and the duration of cannulation for those who required tracheostomy. Adjusted odds ratios (ORs) and 95% confidence intervals (CIs) were computed.

3. Results

A total of 41 patients were enrolled (21 males [51.2%], 20 females [48.8%]). The median age at diagnosis was 29 days (interquartile range [IQR]: 8–54 days). The median age at tracheostomy was 48 days (IQR: 30–81 days). The median age at attainment of vocal fold movement was 2.4 years (IQR: 0.7–4.4 years). The median age at decannulation was 4.8 years (IQR: 1.8–5.7 years). The median duration of cannulation was 4.4 years (IQR: 1.7–5.6 years) (Table 1).

The etiology of BVFI was idiopathic in 31 patients (75.6%) and neurogenic disease in 10 patients (24.4%). The neurologic disorders in neurological group including Arnold Chiari syndrome, Moebius syndrome, corpus collosum dysgenesis, brain atrophy, myasthenia gravis, cerebral palsy, global hypotonia with development delay. At diagnosis, the vocal fold was in the median position in 27 (65.9%), in the paramedian position in 13 (31.7%), and in the lateral position in 1 (2.4%) patient. Twenty-six of 41 patients (63.4%) were found to have concomitant airway disease, including laryngomalacia, tracheomalacia, subglottic stenosis, vocal cord granulation, laryngeal granulation and tracheal bronchus. Airway procedures, including laryngotracheal reconstruction (n = 1), supraglottoplasty (n = 3), tracheal granulation removal (n = 3), vocal fold granulation removal (n = 2) and stomaplasty (n = 5), were implemented for 10 patients (24.4%). Thirty-three (80.5%) patients underwent tracheostomy, 5 (12.2%) patients did not require tracheostomy, 2 (4.9%) patients did not receive tracheostomy, according to their parents’ wishes, and 1 (2.4%) was transferred to another medical facility after diagnosis for other medical management (Table 2). Five patients died during this study, including 3 of those who underwent tracheostomy and the 2 patients who did not receive tracheostomy despite of meeting the criteria.

The position of the vocal fold at diagnosis was a significant factor associated with subsequent tracheostomies (median 100%
vs paramedian 61.5%, \(P = .003\) (Table 3). Twenty-four (24/31, 77.4%) patients were eventually decannulated. The only factor related to decannulation was the patients’ sex (male 60% vs female 94%, \(P = .037\)). This statistical significance disappeared after multivariate regression was performed. There were no statistically significant differences in terms of other variables, such as etiology, position of vocal folds at diagnosis, prematurity, prior intubation, gastroesophageal reflux disease or concomitant airway disease, in relation to decannulation (Table 4).

In terms of the duration of cannulation, those who were found to have attainment of vocal fold movement at an age of less than 1 year had a shorter duration of cannulation than those who were found to have attainment of vocal fold movement after 1 year of age (mean: 2.0 years vs 5.2 years, \(P < .001\)). No other factor was found to have statistical significance in terms of the duration of cannulation. (Table 5). The mean duration between the time of documented attainment of vocal fold movement and the time of decannulation was 1.4 years (range: 0.1–4.6 years).

### 4. Discussion

It is known that tracheostomy may be required in patients with BVFI.\cite{1,2,4,5,7,9} Yet, some patients with BVFI, who receive alternative treatment, such as ventilator support or laryngotracheal intervention, can survive without undergoing tracheostomy.\cite{16,17,18} Tracheostomy aims to provide a secure airway to prevent hypoxic encephalopathy, rescue the respiratory distress caused by airway obstruction, and improve oral feeding.\cite{19} In this 23-year single-institutional retrospective cohort, the overall tracheostomy rate of patients was about 80%. A wide range of tracheostomy rates (9–100%) has been reported in patients with BVFI, which might be due to inconsistent study designs and study populations.\cite{1,4-12} The high tracheostomy rate in this study might have been influenced by the following factors: firstly, the rate of intervention involving the larynx and trachea, such as laryngotracheal reconstruction or vocal fold lateralization, was relatively low in comparison to previous studies, which might have resulted in an increased tracheostomy rate. Secondly, most patients (65.9%) in this study had a median vocal fold position, which might have led to a relatively higher tracheostomy rate. Thirdly, the population in this study had different etiologies, while some previous reports only focused on idiopathic BVFI. Although differences in the rate of tracheostomy for various etiologies have not yet been identified, previous studies that involved multiple etiologies have also reported a higher rate of tracheostomy.\cite{17,9,11,18}

The median age of BVFI diagnosis and performing tracheostomy in this study was 29 and 48 days, respectively. There were a few contributors which could have influenced these results. Firstly, the patients who received tracheostomy had a high prior intubation rate (81.8%). The administration of invasive ventilation would conceal the symptoms of BVFI, thereby delaying the time until flexible laryngoscopy and performing tracheostomy. Secondly, the confirmation of BVFI was established after repeated flexible laryngoscopy, which resulted in a prolongation of the time until tracheostomy. Thirdly, the time caregivers needed for accepting performing tracheostomy played an important role in this issue.

In a previous study, the causes of BVFI were classified into idiopathic (42.2%), cardiac procedure-related (30.4%), neurological (20.6%), mixed etiology (4.9%), and others (1%).\cite{9} Idiopathic BVFI (75.6%) and neurogenic BVFI (24.4%) accounted for the majority of patients in our study. No cardiac surgery-related BVFI was identified in this study, as those patients who required complex cardiac surgery had been transferred to another hospital with the appropriate expertise. Our decannulation rate was 77.4%. The high decannulation rate might be due to the absence of cardiac surgery-related BVFI patients from our study cohort.\cite{1,9} However, we noted no statistically significant difference in the decannulation rate between groups (\(P = .569\)), which might be due to the relatively small number of patients.

In our study population, excepting those 2 patients who did not receive tracheostomy, all patients who had a median vocal fold position at diagnosis, and 8 of 13 patients whose vocal fold position at diagnosis was paramedian, underwent tracheostomy (Table 2). In contrast to a previous study, the difference in the tracheostomy rate between these 2 groups was statistically significant (\(P = .003\)).\cite{9} The higher tracheostomy rate for those with a vocal fold in the median position might be due to the higher airway resistance encountered with this position than for the paramedian vocal fold position.

Our mean duration of cannulation was 4.2 years (Table 1), which is slightly longer than that reported in previous studies.\cite{7,9,10} Several reports have indicated that patients required a procedure, such as arytenoidectomy, vocal fold lateralization, or laryngotracheal reconstruction, to achieve

### Table 2

| Tracheostomies performed in the patient cohort. |
|-----------------------------------------------|
| **Vocal fold position at diagnosis** | **Total** | **Tracheostomy** | **Ongoing** | **Decannulation** | **Died** |
|-----------------------------------------------|
| **Median** | 25 | 25 | 3 | 19 | 3 | 0 |
| **Paramedian** | 13 | 8 | 1 | 5 | 0 | 2 |
| **Lateral** | 1 | 0 | 0 | 0 | 1 | 1 |

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Note:
- Two patients who refused tracheostomy and 1 patient who was transferred to another medical facility were not included.
- Defined as gestational age less than 37 weeks.

### Table 3

| Comparison of data by subsequent tracheostomies. |
|-----------------------------------------------|
| **Variable (N = 38)** | **Yes** | **No** | **P value** |
|-----------------------------------------------|
| **Sex** | 15 (39%) | 4 (11%) | .34 |
| Male | 18 (47%) | 1 (3%) | |
| Female | 25 (66%) | 5 (13%) | .563 |
| **Etiology** | 18 (47%) | 0 (0%) | .003 |
| Idiopathic | 10 (26%) | 6 (16%) | .279 |
| Neurogenic | 8 (21%) | 0 (0%) | .076 |
| **Vocal fold position at diagnosis** | 10 (26%) | 8 (21%) | .615 |
| Median | 25 (66%) | 0 (0%) | |
| Paramedian | 8 (21%) | 0 (0%) | |
| **Prematurity** | 2 (5%) | 2 (5%) | |
| Yes | 31 (79%) | 3 (8%) | |
| No | 27 (71%) | 3 (8%) | |
| **Prior intubation** | 23 (61%) | 6 (16%) | .615 |
| Yes | 16 (42%) | 3 (8%) | |
| No | 12 (32%) | 3 (8%) | |
| **Gastroesophageal reflex disease** | 24 (63%) | 4 (11%) | 1.000 |
| Yes | 9 (24%) | 2 (5%) | |
| No | 11 (29%) | 1 (3%) | |

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Note:
- Two patients who refused tracheostomy and 1 patient who was transferred to another medical facility were not included.
decannulation.[16,17] However, these procedures may interfere with voice quality.[16] In our study, among the 24 patients who eventually underwent decannulation, 9 (36%) underwent an airway procedure, including supraglottoplasty, tracheal or vocal fold granulation removal, stomaplasty and laryngotracheal reconstruction. We performed supraglottoplasty on three patients with severe laryngomalacia in order to prevent tracheostomy but were unable to achieve the goals. Excision of granulation tissue for post-intubation vocal fold granulation or tracheal granulation were performed in 5 patients in order to maintain airway patency. Stomaplasty was performed in 5 patients for the patients who had stoma granulation during the follow-up period. Only 1 patient (4%) underwent laryngotracheal reconstruction with posterior costal cartilage graft for the purpose of facilitating decannulation. We seldom performed arytenoidectomy or vocal fold lateralization in order to preserve the quality of the voice. The longer duration of cannulation in our study could be explained by this lower laryngotracheal intervention rate.

The mortality rates of patients who did and did not undergo tracheostomy were 9.7% and 25%, respectively. Of the 3 patients with tracheostomy who died, 1 death was related to accidental decannulation, and 2 were related to pneumonia with mucus plugging. Three of them died out of hospital without in-time medical aids. The rate of tracheostomy-related death was low, which was consistent with the findings of previous studies.[9,10]

Eight patients did not undergo tracheostomy. Among them, 1 patient was transferred to another medical facility for other medical management, 5 patients who did not meet the criteria for the surgery survived, while another 2 patients did not receive the surgery due to parental refusal, despite meeting the criteria. In 2 patients who died without performing tracheostomy, one had the underlying condition of prematurity with gestational age 28

| Variable (N=31) | Ongoing | Decannulated | P value | OR (95%CI) | P value |
|----------------|---------|--------------|---------|------------|---------|
| Sex            | 6 (19%) | 9 (29%)      | .037    | 0.04 (0.001–1.322) | .072 |
| Male           | 5 (16%) | 20 (65%)     | .569    | 11.16 (0.335–372) | .178 |
| Female         | 2 (6%)  | 4 (13%)      |         |            |         |
| Etiology       | 5 (16%) | 19 (62%)     | 1.000   | 28.23 (0.481–1657) | .108 |
| Idiopathic     | 2 (6%)  | 6 (19%)      |         |            |         |
| Neurogenic     | 2 (6%)  | 6 (19%)      |         |            |         |
| Vocal fold position at diagnosis | 5 (16%) | 19 (62%) | .335 | 12.13 (0.654–225) | .094 |
| Median         | 1 (3%)  | 6 (19%)      |         |            |         |
| Prematurity    | 0 (0%)  | 2 (6%)       | 1.000   | 0.20 (0.011–3.839) | .291 |
| No             | 7 (23%) | 22 (71%)     |         |            |         |
| Prior intubation | 5 (16%) | 20 (65%) | .506 | 0.20 (0.011–3.839) | .291 |
| Yes            | 2 (6%)  | 4 (13%)      |         |            |         |
| No             |         |             |         |            |         |
| Gastroesophageal reflux disease | 3 (9%) | 5 (16%) | .335 | 12.13 (0.654–225) | .094 |
| Yes            | 4 (13%) | 19 (62%)     |         |            |         |
| No             |         |             |         |            |         |
| Concomitant airway disease | 5 (16%) | 17 (55%) | 1.000 | 0.11 (0.048–12.73) | .179 |
| Yes            | 2 (6%)  | 7 (23%)      |         |            |         |
| No             |         |             |         |            |         |
| Airway management | 1 (3%) | 9 (29%) | .379 | 0.12 (0.005–2.681) | .179 |
| Yes            | 6 (19%) | 15 (49%)     |         |            |         |
| No             |         |             |         |            |         |

1 Two patients who were lost to follow up were not included.
2 Three patients who died were viewed as ongoing cannulation.
3 Co-variates included in the logistic regression included sex, etiology of BVFI, vocal fold position at diagnosis, prior intubation, gastroesophageal reflex disease, concomitant airway disease and airway management.
4 Unable to perform logistic regression because of extreme data.

| Variable | Mean (Range), yr | P value |
|----------|-----------------|---------|
| Sex      | .743            |         |
| Male     | 4.0 (1.2–10.7)  |         |
| Female   | 4.4 (0.8–7.7)   |         |
| Etiology | 4.5 (0.8–10.7)  | .217    |
| Idiopathic | 2.7 (1.2–6.1)  |         |
| Neurogenic| 2.7 (1.2–6.1)  |         |
| Vocal fold position at diagnosis | 4.6 (0.8–10.7) | .231 |
| Median   | 2.8 (1.2–7.7)   |         |
| Prematurity | 2.6 (1.0–4.4) | .442 |
| Yes      | 4.3 (0.8–10.7)  |         |
| No       |                 |         |
| Gastroesophageal reflux disease | 3.5 (1.0–4.9) | .285 |
| Yes      | 4.7 (0.8–10.7)  |         |
| No       |                 |         |
| Concomitant airway disease | 3.8 (0.8–6.7) | .342 |
| Yes      | 5.2 (1.4–10.7)  |         |
| No       |                 |         |
| Age at attainment of vocal fold movement | <.001 |
| < 1 yo   | 2.0 (0.8–4.1)   |         |
| > 1 yo   | 5.2 (1.6–10.7)  |         |

yr, year(s); yo, year(s) old.
weeks without other comorbidities. The parents refused tracheostomy due to financial difficulty. The other one had been diagnosed as Moebius syndrome, and the parents refused tracheostomy due to the poor prognosis of the patient. Both of them died soon after the ventilation support was withdrawn.

The factors associated with the duration of cannulation have not been reported previously. We found that patients who had attainment of vocal fold movement at an age of less than 1 year had a shorter cannulation duration than those whose vocal fold immobility resolved only after 1 year of age.

The mean duration between the time of documented attainment of vocal fold movement and the time of decannulation was 1.4 years. This time lapse may be because the attainment of vocal fold movement mentioned here did not indicate the full recovery of vocal fold mobility. Furthermore, the sudden increase in airway resistance after decannulation might cause respiratory difficulty in these long-term tracheostomy-dependent patients. In our institution, we attempted to down-size the tracheostomy tube to make the patient less dependent on the tracheostomy before attempting decannulation.

Despite being performed at a referral tertiary hospital, which is also the most advanced airway-intervention hospital in Taiwan, this study had several limitations. First, this was a retrospective study, and the study population was also relatively small. We also did not study patients with cardiac surgery-related BVFI. Similar to other long-term retrospective studies, the information used in this study was collected from both handwritten and electronic records, which may have influenced the accuracy of the data. To overcome these disadvantages, a large population-based, multicenter prospective study should be conducted in the future.

5. Conclusions
A large proportion of patients with BVFI may require tracheostomy. Those with a median vocal fold position had a higher rate of tracheostomy than those with a paramedian vocal fold position. The outcome of these patients is quite good, and most of them can eventually be decannulated. Earlier attainment of vocal fold movement is predictive of a shorter duration of cannulation. This information is helpful for physicians who attend patients with BVFI and for counseling of families of patients with BVFI.

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