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Screening for Vocal Fold Movement Impairment in Children Undergoing Esophageal and Airway Surgery

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Introduction: Children undergoing cervical and/or thoracic operations are at risk for recurrent laryngeal nerve injury, resulting in vocal fold movement impairment (VFMI). Screening for VFMI is often reserved for symptomatic patients.

Objective: Identify the prevalence of VFMI in screened preoperative patients prior to an at-risk operation to evaluate the value of screening all patients at-risk for VFMI, regardless of symptoms.

Methods: A single center, retrospective review of all patients undergoing a preoperative flexible nasolaryngoscopy between 2017 and 2021, examining the presence of VFMI and associated symptoms.

Results: We evaluated 297 patients with a median (IQR) age of 18 (7.8, 56.3) months and a weight of 11.3 (7.8, 17.7) kilograms. Most had a history of esophageal atresia (EA, 60%), and a prior at-risk cervical or thoracic operation (73%). Overall, 72 (24%) patients presented with VFMI (51% left, 26% right, and 22% bilateral). Of patients with VFMI, 47% did not exhibit the classic symptoms (stridor, dysphonia, and aspiration) of VFMI. Dysphonia was the most prevalent classic VFMI symptom, yet only present in 18 (25%) patients. Patients presenting with a history of at-risk surgery (OR 2.3, 95%CI 1.1, 4.8, $p = 0.03$), presence of a tracheostomy (OR 3.1, 95%CI 1.0, 10.0, $p = 0.04$), or presence of a surgical feeding tube (OR 3.1, 95%CI 1.6, 6.2, $p = 0.001$) were more likely to present with VFMI.

Conclusion: Routine screening for VFMI should be considered in all at-risk patients, regardless of symptoms or prior operations, particularly in those with a history of an at-risk surgery, presence of tracheostomy, or a surgical feeding tube.

Key Words: EA, esophageal atresia, prevalence, recurrent laryngeal nerve injury, RLN, screening, VFMI, vocal fold movement impairment.

Level of Evidence: 3

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INTRODUCTION

Vocal fold movement impairment (VFMI)—decreased or absent mobility of one or both vocal folds—is a contributor to morbidity in patients who have undergone foregut, cardiac, and airway surgery.[1–11] The vocal folds and associated laryngeal muscles control the patency of the airway by acting as a glottic valve, allowing for phonation, tussis, and airway protection during swallowing. The recurrent laryngeal nerve (RLN) provides motor input to all the intrinsic muscles of the larynx except the cricothyroid muscle. It also conveys much of the autonomic and somatic fibers involved in various functions, such as deglutition and coughing.

The RLN traverses two anatomic compartments twice—neck and chest—as it branches from the vagus nerve to its target, the larynx. Hence, one or both RLNs may be at risk of injury in a variety of pediatric cervical and thoracic operations.[12–15] When the RLN is injured, the resultant VFMI may have multiple forms of clinical presentation. Unilateral VFMI may present asymptomatically if the contralateral vocal fold is able to compensate and approximate the immobile vocal fold in the midline or if there is favorable adductor synkinesis of the immobile vocal fold. If the contralateral vocal fold is unable to compensate, the patient may present with dysphonia, commonly noted as a "breathy" voice, or dysphagia with or without aspiration. Early RLN injury often results in flaccid paralysis (lateral fold position and breathy voice, with the fold easily "sucked in"), which can lead to stridor in the small glottis of infants. Over time, spontaneous reinnervation can occur, which can dictate the balance of adductor to abductor activity and thus the extent of vocal fold mobility, the final position of the folds if immobile, and the resultant voice. Bilateral VFMI presents with greater morbidity for the patient. The vocal folds may be immobile in the abducted position, resulting in a wide glottic opening, breathy voice, poor airway protection,

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and a weak cough. Alternatively, if the folds are fixed close to the midline, the glottic opening is significantly narrowed, and the patient may have dyspnea, stridor, and may require a tracheostomy. In summary, these effects from unilateral or bilateral RLN injury predispose children to an increased risk of aspiration, dysphagia, dysphonia, and respiratory difficulties.[1,3,5,7,9,11,16–19]

In adults, the risk of RLN injury, and thus VFMI, varies based on the type of surgery, from 1% to 6% with thyroid surgery to 27% with descending thoracic aortic surgery.[20–22] In children, not only is the nerve smaller—which may be an independent risk factor for injury[23]—but maintaining the integrity of the RLN is imperative due to its role in learning how to safely swallow and speak. In children, the reported frequency of RLN injury varies from 7% to 40%, with most "at-risk" operations being cardiac (e.g., patent ductus arteriosus ligation), cervical, and thoracic (e.g., esophageal atresia) in nature.[1,8,10,11,24–28] The variability in reported injury rates stems from differences in the timing and selection of patients to screen for VFMI.[11,25,29] Many RLN injuries are believed to be temporary, but the natural history of these injuries, particularly in children, remains unclear. Moreover, there is controversy about which patients should be evaluated for VFMI. Some argue that only symptomatic patients should be examined, whereas others believe in routinely evaluating all patients at risk.

To understand the magnitude of VFMI in our patients with complex esophageal and airway disorders, we sought to describe the prevalence and characteristics of VFMI in patients evaluated at our center prior to undergoing an at-risk operation. We hypothesized that the prevalence of VFMI would be high and that symptoms would not be specific, such that routine screening of all patients at risk would be warranted.

METHODS

Inclusion/Exclusion Criteria and Study Population

We conducted an Institutional Review Board (IRB)-approved retrospective review of all patients who underwent a multidisciplinary aerodigestive evaluation at our Pediatric Esophageal and Airway Treatment (EAT) center prior to undergoing an esophageal, airway, or great vessel operation where one or both RLNs were at risk between January 1, 2017 and November 1, 2021. At-risk surgeries were categorized into four broad categories: esophageal, airway, great vessel-related, or a combination. At-risk esophageal procedures included primary esophageal repair, traction-induced esophageal lengthening (Foker) repair, esophageal stricturoplasty or resection, jejunal interposition, cervical esophagostomy, esophageal duplication cyst resection, esophagectomy, esophagopulmonary fistula repair, tracheoesophageal fistula repair (primary, recurrent, or acquired), esophageal diverticulum resection, and esophageal leak or perforation repair. At risk airway procedures included anterior or posterior tracheopexy, mainstem bronchopexy, aortopexy (any part), pulmonary arteriopexy, and tracheal diverticulum resection. At-risk great vessel-related procedures included division and reimplantation of an aberrant subclavian artery (right or left), division of the double aortic arch, aortic uncrossing, patent ductus arteriosus ligation, resection of the diverticulum of Kommerell, and pulmonary sling repair.

At the start of the study period, patients were preoperatively selected for screening in respect to the presence of symptoms concerning VFMI. As the study period progressed, there became a multi-disciplinary shift toward screening all patients, despite their symptoms, prior to undergoing an at-risk surgery. Adoption was gradual in implementation due to the COVID-era, with an attempt to balance provider safety (Fig. 1). In total, only patients who underwent a preoperative awake, non-sedated, flexible nasolaryngoscopy by a fellowship-trained pediatric otorhinolaryngologist were included in the study. Non-diagnostic studies were excluded.

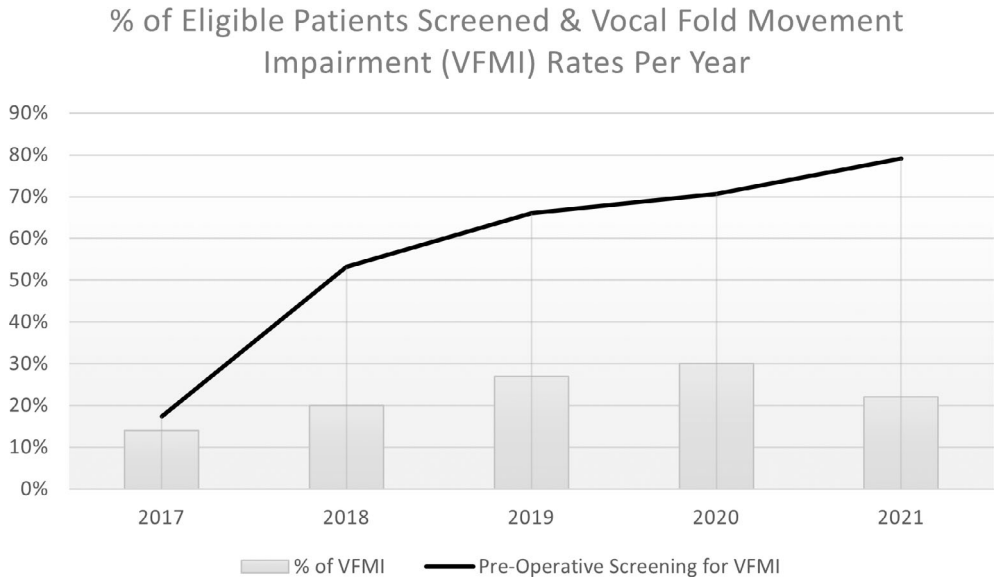

Fig. 1. Percentage of eligible patients screened and vocal fold movement impairment (VFMI) rates per year.

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Outcome Measurement and Study Variables

The primary outcome measure was the presence of VFMI at the time of preoperative vocal fold evaluation via awake flexible nasolaryngoscopy, as documented in the procedure note. VFMI was defined as either hypomobility or immobility of one or both vocal folds. Hypomobility or immobility was defined as a deviation from normal cord movement, particularly during phonation, which included partial or complete paresis. Secondary outcomes include symptoms at the time of examination documented in the medical record, presence of a surgical feeding tube, and respiratory status. Symptoms that are potentially associated with VFMI were extracted from the medical record as either documented observations by a provider or parent and broadly categorized into three groups: dyspnea, dysphonia, and aspiration. Dyspnea included stridor, shortness of breath with exertion, and observed labored breathing. Dysphonia includes a weak, raspy, breathy, or hoarse cry or voice. Aspiration included a history of an abnormal modified barium swallow study.

Demographics, clinical characteristics, and prior operative history were also abstracted from the medical record. Clinical characteristics included diagnostic history (EA, tracheomalacia, laryngomalacia, etc.), presence or history of a cardiac defect, presence of a tracheostomy, presence of a surgical feeding tube, and oxygen requirement. Cardiac defects included were atrial septal defects, ventricular septal defects, double outlet right ventricle, tetralogy of Fallot, transposition of the great vessel, aortic coarctation, hypoplastic left heart, dextrocardia, and absence of the pulmonary valve. Descriptive statistics are provided.

Statistical Analysis

Descriptive characteristics for demographics and clinical characteristics were presented as frequency (%) and median (IQR) for categorical and continuous variables, respectively. Associations between the presence of VFMI and clinical characteristics were evaluated with univariable parametric and nonparametric tests, including chi-square for categorical variables and Wilcoxon rank sum for continuous variables. Clinical features found to be significantly associated with VFMI on univariable analysis were included in a multivariable logistic regression model. p-values less than 0.05 were considered significant. Analyses were performed with JMP Pro 15 (SAS, Cary, NC).

RESULTS

Demographics

During the timeframe of the retrospective review, 515 patients were evaluated at our center, of whom 297 (58%) underwent a preoperative vocal fold examination by an awake flexible nasolaryngoscopy. Screening for VFMI gradually increased over the course of the study (Fig. 1). The majority of patients were male (59%) and had a history of EA (60%), with type C predominance (68%). The median age was 18 months (IQR: 7.8, 56.3) and weight 11.3 kg (IQR: 7.8, 17.7), Table I. Twenty-eight (9%) patients had a tracheostomy present, and almost half (49%) had a surgical

TABLE I.
Demographic and Preoperative Variables.

	n (%) or Median (IQR) *n* = 297 Patients	(+) VFMI *n* = 72 Patients	(–) VFMI *n* = 225 Patients
Males, *n* (%)	175 (59%)	40	135
Age (months)	18 (7.8, 56.3)	17.5 (9, 56.3)	17 (6, 54)
Operative weight (kg)	11.3 (7.8, 17.7)	10.8 (8.7, 16.8)	11.9 (7.7, 18.9)
History of esophageal atresia	178 (60%)	56 (78%)	122 (54%)
Type A	32 (18%)	10 (14%)	22 (10%)
Type B	15 (8%)	5 (7%)	10 (4%)
Type C	121 (68%)	37 (51%)	84 (37%)
Type D	7 (4%)	1 (1%)	6 (3%)
Type E	3 (2%)	3 (4%)	0 (0%)
VACTERL	94 (32%)	37 (51%)	57 (25%)
History of laryngomalacia	47 (16%)	14 (19%)	33 (15%)
Laryngeal cleft (any type)	141 (47%)	32 (44%)	109 (48%)
History of subglottic stenosis (any grade)	51 (17%)	14 (19%)	37 (16%)
Tracheomalacia	263 (88%)	64 (89%)	199 (88%)
History of cardiac defect*	112 (38%)	37 (51%)	75 (33%)
History of great vessel anomaly†	91 (31%)	21 (38%)	70 (31%)
History of surgery (any)	217 (73%)	62 (86%)	155 (69%)
History of at-risk surgery	178 (60%)	58 (81%)	120 (53%)
Enteral feeding tube present	146 (49%)	53 (74%)	93 (41%)
Tracheostomy present	28 (9%)	18 (25%)	10 (4%)

*ASD = atrial septal defect; VSD=ventricular septal defect; DORV=double outlet right ventricle; TOF = tetralogy of Fallot; TGA = transposition of great arteries; COA = coarctation of aorta; HLH = hypoplastic left heart; DC = dextrocardia; APV = absent pulmonary valve.

†DAA = double aortic arch; RAA = right aortic arch; CA = circumflex aorta; ABLSA = aberrant left subclavian artery; ABRSA = aberrant right subclavian artery; IACS = innominate artery compression syndrome; DK = diverticulum of Kommerell, PS = pulmonary stenosis.

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feeding tube present. A majority (60%) had a history of a prior at-risk surgery (Table I).

Prevalence and Distribution of VFMI

Of the 297 patients evaluated, 225 (76%) had normal vocal fold motion bilaterally. Seventy-two patients (24%) had VFMI on flexible nasolaryngoscopy. As screening rates increased over time, we saw an increase in VFMI rates as well (Fig. 1). Of those with VFMI, 18 (26%) had right-sided impairment, 38 (51%) had left-sided impairment, and 16 (22%) had bilateral impairment.

Symptoms

Of the 72 patients with VFMI, only 38 (53%) had symptoms documented in the medical record that are classically associated with VFMI, including dysphonia, stridor, recurrent respiratory infections, dyspnea, or a history of aspiration. Of those with symptoms, dysphonia was the most prevalent symptom (18/38, 47%), followed by recurrent respiratory infection (7/38, 18%), evidence of aspiration on MBS (6/38, 16%), stridor (5/38, 13%), and shortness of breath with exertion (2/38, 5%). Five patients had more than one symptom. Patients with bilateral VFMI were more likely to present with symptoms (81% vs. 45% unilateral, OR 5.3, 95%CI 1.37, 20.96, $p = 0.01$). For those with unilateral VFMI, laterality of impairment was not associated with a greater likelihood of being symptomatic (39% left vs. 56% right, $p = 0.3$), Figure 2.

Pre-Operative Associations with VFMI

On univariable analysis, a history of EA, history of a prior at-risk surgery, cardiac defect, presence of a surgical feeding tube, oxygen requirement, and presence of a tracheostomy were significantly associated with a VFMI (Table II). On multivariable analysis, history of a prior at-risk surgery (OR 2.3, 95% CI 1.1, 4.8, $p = 0.02$), presence of a surgical feeding tube (OR 3.1, 95% CI 1.6, 6.2, $p = 0.001$), and presence of a tracheostomy (OR 3.1, 95% CI 1.0, 10.0, $p = 0.04$) remained significantly associated with VFMI, Table II. Notably, 14 (19%) patients with a VFMI had no prior at-risk operation. Although, as a whole, the type of EA was not significantly associated with VFMI, all three patients with a history of an H-type tracheoesophageal fistula (EA type E) repair were noted to have VFMI.

TABLE II.
Associations with Vocal Fold Movement Impairment (VFMI).

	Univariable		Multivariable		
	VFMI, *n* (%)	*p*-Value	OR	95% CI	*p*-Value
History of EA					
Yes ($n = 178$)	56 (31%)	0.0003	1.8	0.83–3.93	0.13
No ($n = 119$)	16(13%)		0.55	0.25–1.21	
History of cardiac defect					
Yes ($n = 112$)	37 (33%)	0.007	1.37	0.75–2.52	0.3
No ($n = 185$)	35 (19%)		0.73	0.39–1.33	
Feeding tube					
Yes ($n = 146$)	53 (36%)	<0.0001	3.15	1.6–6.21	<0.001
No ($n = 151$)	17 (11%)		0.32	0.16–0.63	
Respiratory status (room air)					
Yes ($n = 246$)	51 (21%)	0.016	1.2	0.53–2.71	0.65
No ($n = 51$)	21 (37%)		0.83	0.37–1.87	
Tracheostomy					
Yes ($n = 28$)	10 (36%)	0.011	3.18	1.01–10.0	0.04
No ($n = 269$)	62 (23%)		0.31	0.1–0.99	
History of at-risk surgery					
Yes ($n = 178$)	58 (33%)	<0.001	2.29	1.1–4.79	0.03
No ($n = 119$)	14 (12%)		0.44	0.21–0.91	

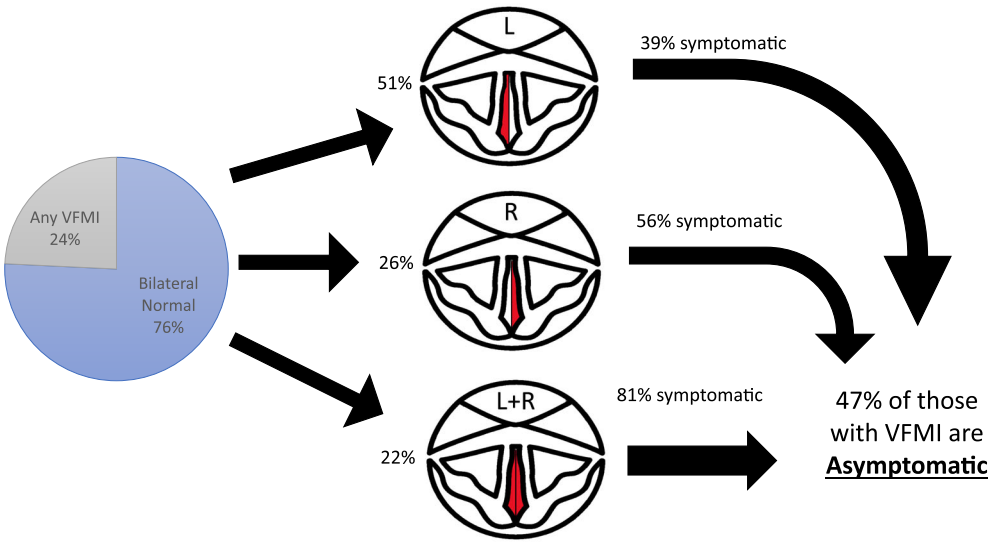

Fig. 2. Prevalence of vocal fold movement impairment (VFMI) in pre-operative vocal fold checks and symptom distribution. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

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DISCUSSION

Our study results demonstrate that VFMI is present in up to a quarter of patients evaluated at a pediatric referral aerodigestive program. Patients with a history of a prior at-risk surgery, surgical feeding tube, or tracheostomy are more likely to present with a VFMI. Of note, 47% of patients with a VFMI did not exhibit symptoms classically associated with VFMI, such as dysphonia, dyspnea, or aspiration. This finding underscores the importance of routine screening of at-risk patients for VFMI regardless of symptoms. The frequency of VFMI in patients without a prior at-risk operation is surprising at almost 1 in 5 patients (19%), and suggests a possible congenital etiology.[30,31] Given the prevalence of VFMI in our patient population and the poor discriminatory nature of relying on symptoms alone, we recommend a strategy of routine screening of all patients at risk, regardless of symptoms or prior surgical history.

Our results are in accordance with what others have reported,[8,10,11,25] particularly in patients with a history of EA. Fung and colleagues reported VFMI in up to 50% of patients with an H-type tracheo-esophageal fistula repair and similarly encountered a left-sided predominance to VFMI.[10] Despite most EA repairs being approached from the right chest, the longer intrathoracic course of the left RLN as it wraps around the aortic arch makes it particularly vulnerable during EA repairs, explaining this left-sided predominance.[14]

Implications of VFMI

VFMI in the pediatric population following RLN injury results in significant morbidity and may be a result of congenital, idiopathic, post-viral, or iatrogenic causes.[17] RLN injury and resultant VFMI can impair the ability to produce sounds and vocalize properly. This may delay the acquisition of language skills. The vocal folds are an important part of the laryngeal adductor reflex which protects the airway during deglutition. Moreover, learning to safely swallow is a complex, coordinated reflex that matures postnatally. An injured RLN and abnormal vocal fold movement can impair and delay the acquisition of this reflex,[18,32] ultimately leading to feeding difficulties, aspiration and recurrent infections, surgical feeding tubes, and possibly oral aversion. Perhaps most acutely important is the role the vocal folds have in maintaining the size of the glottic aperture for breathing. VFMI can limit the extent to which the glottis opens during inhalation and exhalation, which can lead to airflow limitation and respiratory distress.

The natural history of the recovery of vocal fold function is multifaceted. Several studies have suggested that rates of recovery based on endoscopic evaluation depend on the mechanism or context of injury, with surgical etiologies of injury having the highest percentage of recovery.[1,7,8,28] Pantvaidya et al describe a mean duration of spontaneous functional recovery to be approximately 7 months, with other groups finding a range of recovery between 1 and 26 months.[17,33] They describe only 3.5% of their cohort having a permanent palsy after known injury in adults undergoing thyroidectomy.[33] Knowing this and given that the time intervals between at-risk surgical events and our assessments were varied, we can infer that our estimates are likely underestimating the true prevalence of VFMI due to the expectation that a large proportion of injuries could have spontaneously recovered prior to our endoscopic assessment. Not only is it critical that VFMI be detected to understand the true prevalence of injury, but it is also important to evaluate potential silent aspiration and provide additional resources for these patients as VFMI is known to increase respiratory morbidity.[9] Thus, routine screening before and after at-risk operations is imperative.

Implications for Practice

Awareness of vocal fold functional status is imperative in the evaluation and management of children with aerodigestive disorders, particularly in those who are failing to thrive or who may need another operation that may also place the RLNs at risk. Though we do not yet have the data to demonstrate that knowing preoperative VFMI status improves outcomes, we certainly believe that knowing preoperative VFMI status matters and positively impacts our management in several ways: (1) Improved preoperative understanding and awareness of all issues affecting the patient. This leads to the evaluation of aspiration risk via modified barium swallow tests and the potential for preoperative pulmonary optimization via dietary modifications if the patient is silently aspirating. (2) More accurate counseling of operative risks to parents/patients. (3) Incorporation of preoperative VFMI status in operative planning. To decrease the risk of future VFMI, we may alter the body cavity or the laterality with which we approach the procedure. Like other head and neck surgeries, where there is concern for intraoperative nerve injury and the case alters from, for example, a total thyroidectomy to a hemithyroidectomy, it is imperative to the surgical plan to prevent the devastating consequences of bilateral vocal fold impairment. (4) Improved ability to achieve a successful intraoperative nerve monitoring strategy by being able to interpret RLN neuromonitoring signals in the setting of known preoperative VFMI status. This often helps us detect the prior site of injury and understand its potential prognosis for recovery (e.g., intact Vagus-RLN loop, weak amplitude vs. no signal). (5) Identification of patients at high risk for postoperative extubation failure or aspiration risk. Patients with preoperative VFMI are more likely to undergo early postoperative screening for additional VFMI to limit airway morbidity, and (6) Patients/parents appreciate knowing their VFMI status and allows all of us to be more honest with our outcomes.

Strategies to monitor and protect the RLN during at-risk operations exist in the form of intraoperative RLN monitoring (IONM) techniques, and these have been successfully adapted and implemented for children as young as neonates.[34–40] In our practice and since performing this retrospective review, we now routinely use IONM in all our at-risk surgical procedures and screen all patients for evidence of VFMI before and after each

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procedure with awake flexible laryngoscopy. Pre- and post-operative vocal fold evaluations also allow the surgeon to monitor his or her own VFMI outcomes. Future research should evaluate the impact of such intraoperative nerve monitoring strategies on the rates of RLN injury and resultant VFMI.

We recognize that the implementation of a routine screening model can be challenging, as it was for us. Despite efforts to achieve 100% screening, this is sometimes not possible. Factors to consider when implementing a routine screening model are: (1) Education on the importance of routine screening and buy-in from all stakeholders and services involved; (2) Patient and parent acceptance and tolerance of the diagnostic procedure; (3) Preoperative intubation status; (4) Weekend or holiday admissions or discharges; and (5) Pandemic-like scenarios that may affect the availability of sterile scopes, personal protective equipment, and provider safety. Efforts aimed at addressing the above scenarios will help with the success of implementing a routine screening strategy and achieving maximum capture.

Limitations

This study has several limitations that we acknowledge. Our practice and patient population are very heterogeneous and complex, and likely not reflective of other centers. Nonetheless, the number of patients seen in our center and included in this study allows us to draw conclusions that otherwise would not be possible if we were to focus on only one disease entity. We recognize that selection bias could exist as only 57% (297/515) of patients evaluated during the study period underwent VFMI screening and hence met inclusion criteria. Our VFMI screening practices changed during the study period from selective (screening only symptomatic patients) to routine for all patients. Despite this, we are still unable to reach 100% capture of our population due to the circumstances mentioned in the prior section. Our team's recognition of the magnitude of the problem stimulated this transition, which happened gradually through the midpoint of the study period. Furthermore, during the COVID-19 pandemic, we limited VFMI screening to only symptomatic patients to limit potential exposure to providers from aerosol generating diagnostic procedures. We recognize that these changes in screening practices could affect the prevalence of VFMI in our cohort and introduce selection bias, yet we believe them to be reflective of regular clinical practice, and if bias exists, it is likely biased toward an underestimation of the true prevalence of VFMI, as many potential patients without the classic symptoms of VFMI prompting screening could have been missed. Ascertainment bias could also exist in the diagnosis of VFMI. VFMI can present as a spectrum of impairments, ranging from hypomobility to immobility. The distinction of hypomobility to immobility can be subtle, and different clinicians might evaluate the motion of the same vocal fold differently, particularly when utilizing flexible nasolaryngoscopy in children.[41] To minimize bias and variability in the ascertainment of the VFMI, we ensured that assessments were only made by members of the otorhinolaryngology team who routinely perform awake flexible laryngoscopy, and we documented any deviation from normal with both immobility and hypomobility as VFMI (i.e., anything not normal mobility).

Awake flexible nasolaryngoscopy, albeit the standard of care in screening and diagnosis of VFMI, is invasive and poorly tolerated by some children.[42,43] It is considered an aerosol generating procedure and requires specialized equipment and personnel that may be limited in resource-constrained environments, especially in the COVID-19 era. Recently, there has been growing interest in the use of ultrasound as an alternative VFMI screening modality.[44–46] If demonstrated to be reliable and accurate, ultrasound may facilitate a more widespread adoption of routine screening for at-risk patients.

Retrospective studies, such as this one also rely on the accuracy and completeness of the medical record. It is possible that symptom capture in the medical record does not reflect the true symptom burden of these patients. In particular, regarding symptoms and VFMI, future prospective studies with standardized symptom questionnaires would be more valuable to evaluate the relationship between VFMI and symptomatology.

Conclusion

Approximately one-quarter of patients screened for VFMI prior to an at-risk operation had VFMI, with left-sided impairment being the most prominent. Moreover, bilateral VFMI was more likely to be symptomatic at the time of evaluation, whereas the majority of unilateral VFMI were asymptomatic, Figure 2. Furthermore, almost half of patients with VFMI had no symptoms at the time of vocal fold evaluation, and almost 1 in 5 patients with VFMI had no prior history of at-risk surgery. Despite this, history of prior at-risk surgery, presence of a tracheostomy, and presence of a surgical feeding tube were identified as significant independent variables associated with the presence of VFMI. These results demonstrate that routine screening for VFMI should be conducted in all at-risk patients, regardless of symptoms or prior operations, particularly in patients with a history of an at-risk surgery, tracheostomy, or a surgical feeding tube. Further studies are essential to help guide the development of guidelines for the screening, management, and prevention of VFMI in the pediatric population.

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