Review

Surgical Interventions for Pediatric Unilateral Vocal Cord Paralysis
A Systematic Review

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IMPORTANCE The most widely used surgical interventions for pediatric unilateral vocal cord paralysis include injection laryngoplasty, thyroplasty, and laryngeal reinnervation. Despite increasing interest in surgical interventions for unilateral vocal cord paralysis in children, the surgical outcomes data in children are scarce.

OBJECTIVE To appraise and summarize the available evidence for pediatric unilateral vocal cord paralysis surgical strategies.

EVIDENCE REVIEW MEDLINE (1946-2014) and EMBASE (1980-2014) were searched for publications that described the results of laryngoplasty, thyroplasty, or laryngeal reinnervation for pediatric unilateral vocal cord paralysis. Further studies were identified from bibliographies of relevant studies, gray literature, and annual scientific assemblies. Two reviewers independently appraised the selected studies for quality, level of evidence, and risk of bias as well as extracted data, including unilateral vocal cord paralysis origin, voice outcomes, swallowing outcomes, and adverse events.

FINDINGS Of 366 identified studies, the inclusion criteria were met by 15 studies: 6 observational studies, 6 case series, and 3 case reports. All 36 children undergoing laryngeal reinnervation (8 studies) had improvement or resolution of dysphonia. Of 31 children receiving injection laryngoplasty (6 studies), most experienced improvement in voice quality, speech, swallowing, aspiration, and glottic closure. Of 12 children treated by thyroplasty (5 studies), 2 experienced resolution of dysphonia, 4 had some improvement, and 4 had no improvement (2 patients had undocumented outcomes). Thyroplasty resolved or improved aspiration in 7 of 8 patients.

CONCLUSIONS AND RELEVANCE Published studies suggest that reinnervation may be the most effective surgical intervention for children with dysphonia; however, long-term follow-up data are lacking. With the exception of polytetrafluoroethylene injections, injection laryngoplasty was reported to be a relatively safe, nonpermanent, and effective option for most children with dysphonia. Thyroplasty appears to have fallen out favor in recent years because of difficulty in performing this procedure in children under local anesthesia, but it continues to be a viable option for children with aspiration.

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Unilateral vocal cord paralysis (UVCP) is defined as immobility of a vocal cord due to disruption of its motor innervation.[1] In the pediatric population, UVCP most commonly arises from iatrogenic recurrent laryngeal nerve injury during cardiac surgery. Other origins include iatrogenic injury from neck or mediastinal surgery as well as neurologic and idiopathic causes.[2] A pediatric otolaryngologist in a tertiary care center may expect to see approximately 4 to 10 patients with UVCP each year.[1,3,4]

Neonates and infants with UVCP typically present within the first 2 years of life with an abnormal cry or voice, stridor, or feeding difficulty.[1] Over time, many children achieve spontaneous symptomatic resolution due to compensation in glottic closure from the contralateral vocal cord or recovery of the injured nerve.[2,5] Unfortunately, 20% to 40% of children remain symptomatic after the recommended 8 to 12 months of observation and are considered candidates for surgical intervention.[2,6] The main indication for intervention in young children is airway protection. In older children, dysphonia becomes the primary reason for an intervention.[7] With an increased understanding of the negative effect of dysphonia on the lives of children,[8] some authors[9] have advocated earlier interventions for children with UVCP and dysphonia.

The interest in surgical interventions for pediatric UVCP has increased in the past 15 years. The 3 accepted surgical interventions for glottic closure improvement in children with UVCP are injection laryngoplasty, thyroplasty, and laryngeal reinnervation.[10] In injection laryngoplasty, glottic closure is improved by injecting the thyroarytenoid muscle in the paralyzed cord; however, these results may be temporary because some injection materials are reabsorbed over time. In thyroplasty, the paralyzed vocal cord is medialized permanently with an implant positioned by an external neck incision. Thyroplasty is generally reserved for adolescents who are able to tolerate the procedure while awake so that phonation can be tested for optimal vocal cord positioning.[7] Ansa cervicalis nerve to recurrent laryngeal nerve (ansa-RLN) reinnervation can restore the tone of paralyzed laryngeal muscles. Reinnervation may overcome the concerns about laryngeal growth, ongoing muscle atrophy, or the use of foreign material associated with the other 2 procedures, but there is a significant time lag between surgery and improvement.[11]

Despite increasing interest in surgical interventions for pediatric UVCP, the data on outcomes of these procedures in children are scarce. The goal of this systematic review is to synthesize and summarize available evidence on injection laryngoplasty, thyroplasty, and laryngeal reinnervation for pediatric UVCP. This information will help guide otolaryngologists in choosing an appropriate surgical technique for their patients.

Methods

Literature Search Strategy

We searched MEDLINE (1946 to 2014) and EMBASE (1980 to 2014) for relevant studies. The date of the last search was June 30, 2014. In addition, 2 authors (O.B., B.M.) screened the bibliographies of all relevant studies and searched available abstracts by hand from relevant scientific assemblies from 2003 through 2013: American Academy of Otolaryngology–Head and Neck Surgery, Canadian Society of Otolaryngology, American Society of Pediatric Otolaryngology, and European Society of Pediatric Otorhinolaryngology.

Study Selection Criteria

Two reviewers (O.B., B.M.) screened titles or abstracts from the initial search for the following inclusion criteria: (1) a primary research study (controlled trial or observational study, including case series and case reports); (2) study included data on the pediatric population (0-18 years old); (3) study investigated UVCP and 1 or more of the 3 surgical techniques: injection laryngoplasty, thyroplasty, and/or laryngeal reinnervation; (4) study documented outcomes of the surgical interventions for UVCP; (5) English-language study; and (6) not a duplicate study or a study on the same data set.

The same reviewers then screened the full texts of all chosen citations; studies that did not meet the selection criteria were excluded. All discrepancies were resolved by consensus.

Assessment of Quality, Level of Evidence, and Risk of Bias

The level of evidence from individual studies was assessed using the Oxford Centre for Evidence-Based Medicine Levels of Evidence from March 2009.[12] The risk of selection, performance, detection, attrition, and reporting bias in case series were assessed by determining a score from 0 (low risk) to 5 (high risk) using the following scoring system: (1) sample selection (consecutive or not: 1 indicates no or not stated and 0 indicates consecutive); (2) diagnostic criteria stated (1 indicates not stated and 0 indicates stated); (3) outcomes measured consistently for all patients (1 indicates not consistent and 0 indicates consistent); (4) outcomes reported consistently for all patients (1 indicates not consistent and 0 indicates consistent); and (5) follow-up period of 1 year or more (1 indicates <1 year and 0 indicates ≥1 year).

Data Extraction and Analysis

Data were extracted in duplicate using data forms and outcome measures developed a priori. Descriptive statistics were extracted, and qualitative syntheses of the results were reported. The primary outcome measure was the effect of the surgical intervention on voice as judged by clinical assessment and change in voice-related quality-of-life surveys. The secondary outcome measures were the effect of surgical intervention on swallowing, glottic closure as assessed by endoscopy, and adverse events.

Results

Study Selection

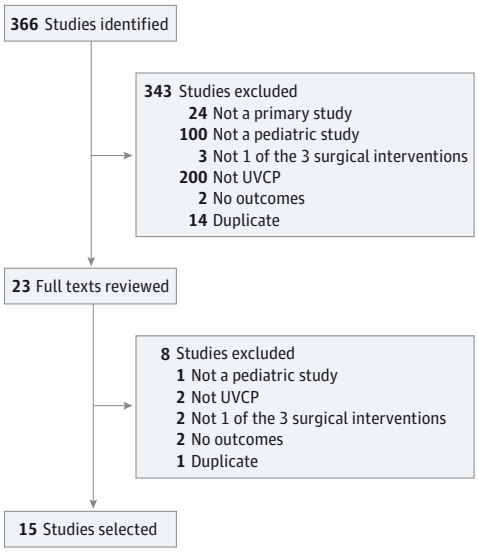
Using our search strategy, we identified 366 studies; 343 were excluded after review of title or abstracts, and 8 studies were excluded after full-text review. This yielded 15 studies for data extraction (**Figure**).

Injection Laryngoplasty

Six studies[1,13-17] reported on injection laryngoplasty for treatment of pediatric UVCP (**Table 1**). Thirty-one patients with a variety of UVCP origins were included in the studies (5 male patients, 3 female patients, and 23 patients with unknown sex). The mean age of the patients was 7.2 years (range, 1 month to 18 years). Dysphonia was the most common indication for injection laryngoplasty (at least 14 patients). In at least 5 patients, injection was performed for aspiration.

A few authors described the methods for injection laryngoplasty in detail. During the procedure, the airway was managed using

Figure. Study Selection



UVCP indicates unilateral vocal cord paralysis.

a variety of techniques: endotracheal intubation, total intravenous anesthesia with spontaneous respiration, jet ventilation, and tracheostomy. Local anesthesia was not used for any of the injections. A number of different injection materials were used (Table 1), but only 2 authors reported the injected volumes. Levine et al[14] used an absorbable gelatin sponge (Gelfoam; Pfizer Inc) and polytetrafluoroethylene and recommended injecting 0.3 to 0.4 mL twice with the Arnold-Bruennings syringe (once into the middle or posterior one-third of the true vocal process and once into the junction of the middle one-third and anterior one-third). Cohen et al[17] reported injecting 0.26 mL of calcium hydroxylapatite (Radiesse Voice; Merz Aesthetics Inc), 0.27 mL of sodium carboxymethylcellulose gel (Radiesse Voice Gel; Merz Aesthetics Inc), and 0.5 mL of an absorbable gelatin sponge (Gelfoam). Overall, the injected volumes varied from 0.2 to 0.6 mL depending on the injected material.

Injection laryngoplasty consistently improved swallowing and voice in children with UVCP in the 6 selected studies. Of 5 patients in whom injection was performed for recurrent aspiration, 3 patients with tracheotomies were decanulated,[13,14] one was weaned from the ventilator, and one stopped having choking episodes.[15] Dysphonia was the indication for 26 vocal cord injections (excluding the study by Cohen et al[17]). All 26 injections were deemed successful in improving voice by subjective measures. Objective measures of voice, including videostroboscopy and computerized voice analysis, were only documented in one patient.[15] Cohen et al[17] were the only authors to report success rates of less than 100% after injection laryngoplasty. Among patients injected for dysphonia, 94% experienced subjective or objective improvement in voice, and among patients injected for dysphagia or aspiration, improvement was seen in 85%. However, in addition to 8 patients with UVCP, this analysis included the outcomes of 5 patients with vocal cord scarring or atrophy.[17] Time to the additional injection was underreported and varied depending on the injected material (Table 1). Tucker[13] and Sipp et al[16] noted the effects of some injectables to last longer than they would expect in the adult population.[13,16] In the 6 studies, one patient with UVCP experienced a complication after vocal cord injection: granuloma formation after polytetrafluoroethylene injection.[1]

Thyroplasty

Five case reports (level 4 evidence) reported using thyroplasty in 12 pediatric patients (**Table 2**).[1,16,18-20] The mean age of the patients was 11.5 years (range, 2-18 years). Dysphonia and aspiration were indications for surgery in 8 patients, whereas 4 patients had dysphonia alone. Local anesthesia was used in 4 patients (aged 14-18 years). General anesthesia was used in 7 patients (aged 2-14 years). Several authors[16,20] advocated the use of laryngeal airway mask for intraoperative airway management.

Voice outcomes were not evaluated objectively in any of the studies. The authors relied on subjective reports by physician, parent, or patient to evaluate voice outcomes. Overall, thyroplasty was moderately effective in alleviating dysphonia. Five (42%) of 12 patients had resolution or improvement of dysphonia after thyroplasty. There were no apparent differences in rates of recovery from dysphonia in patients who underwent thyroplasty under general or local anesthesia. Dysphonia resolved or improved in 3 (43%) of 7 patients and 2 (50%) of 4 patients who underwent thyroplasty under general and local anesthesia, respectively. The laryngeal airway mask was used for 2 of 3 cases in which dysphonia was resolved while the patient was under general anesthesia. Link et al[19] attributed the lack of voice improvement in 3 patients to the use of an adult thyroplasty technique in which the prosthesis was placed above the vocal cords. The authors adjusted the adult technique in their last case by lowering the implant placement and reported a successful voice outcome.

Compared with voice improvement, thyroplasty was more effective in alleviating aspiration. Seven (88%) of 8 patients had resolution or improvement in aspiration after thyroplasty. The remaining 1 patient had effects of the thyroplasty deteriorate at approximately 6 months. However, this patient had a complicated preoperative history, including 3 failed polytetrafluoroethylene injections and an arterectomy that led to intractable aspiration.[18] There were no apparent differences in rates of recovery from aspiration in surgical patients under general or local anesthesia.

During the period of follow-up (range, 4-19 months), 4 of 12 patients had no complications, while complications were not mentioned in 7 patients. One patient had a major complication, aspiration pneumonia, that resulted in a 7-day period of intubation. In this 18-year-old patient, thyroplasty was performed, in addition to adduction arytenoidopexy and cricothyroid joint subluxation, with the patient under local anesthesia.[16]

Reinnervation

We identified 8 studies that reported outcomes of laryngeal reinnervation for UVCP in a pediatric population (**Table 3**).[7,9,13,16,21-24] These studies consisted of case reports and case series (level 4 evidence). Risk of bias was 5 in all except 2 studies.[22,24]

The population of patients in these 8 studies included children aged 2 to 16 years. The cause of UVCP in most of these patients (26 of 38) was patent ductus arteriosus ligation. Dysphonia was the indication for surgery in 37 of 38 patients.

Laryngeal electromyography (EMG) was not used in deciding the timing of surgical intervention in the included studies. How-

Table 1. Studies Reporting on Injection Laryngoplasty for Pediatric UVCP

Source (No. of Patients)	Level of Evidence/ Risk of Bias	Age, Mean (Range), y	UVCP Origin (No. of Patients)	Indication	Injected Material (No. of Injections)	Time to Additional Injection, mo	Results			Adverse Events (No. of Events)
							Voice	Swallow	Glottic Closure	
Tucker,[13] 1986 (2)	4/5	NA	NA	Aspiration	Gelatin sponge (2)	NA	NA	Improvement	NA	None
Levine et al,[14] 1995 (3)	4/5	11	Neurologic	Dysphonia and aspiration	Gelatin sponge (1)	NA	Improvement	Improvement	Improvement	None
		4	Idiopathic	Aspiration	Polytetrafluoroethylene (1)	NA	NA			
		7	Cardiac surgery		Polytetrafluoroethylene (1)	NA			NA	
Daya et al,[1] 2000 (2)	4/5	NA	Cardiac surgery	Dysphonia	Polytetrafluoroethylene (2)	NA	Improvement in 1 patient	NA	NA	Granuloma (1)
Patel et al,[15] 2003 (4)	4/4	5	Neurologic	Aspiration	Cadaveric dermis (6)	3-6	Improvement	Improvement	NA	None
		5	PDA ligation	Dysphonia			Improvement	NA		
		1 mo	Idiopathic	Aspiration			NA	Improvement	Improvement	
		18	Idiopathic	Dysphonia			Improvement	NA		
Sipp et al,[16] 2007 (12)	4/5	10.5 (2.5-18)	Thoracic surgery (5), prolonged intubation (4), and neurologic origin (3)	Dysphonia	Cadaveric dermis (11)	3-9	Improvement	NA	NA	None
					Sodium carboxymethylcellulose gel (1)	NA				
					Bovine collagen (1)	NA				
					Calcium hydroxylapatite (1)	NA				
					Hydrated gelatin powder (3)	1				
					Autologous fat (3)	1-6				
Cohen et al,[17] 2011 (8)	4/5	NA	Neck cannula (1), idiopathic (1), and NE (6)	Dysphonia and aspiration (1), aspiration (1), and NE (6)	Gelatin sponge (NE)	2.2 (range, 1.1-3.5)	NE: see text	NE: see text	NA	None
					Sodium carboxymethylcellulose gel (NE)	NA				
					Calcium hydroxylapatite (NE)	7.3 (range, 1.5-9.7)				

Abbreviations: NA, not applicable or stated; NE, not extractable; PDA, patent ductus arteriosus; UVCP, unilateral vocal cord paralysis.

ever, Zur[23] described using intraoperative EMG to establish the asymmetry between the right and left thyroarytenoid muscles. The authors did not provide information on whether any of the planned reinnervation procedures were aborted as a result of unexpected intraoperative EMG findings.

Ansa-RLN anastomosis was the reinnervation approach used in all identified studies. Smith et al[22] used ansa-RLN anastomosis in combination with arytenoid adduction in older children. Only 2 studies described the surgical technique in detail: one using a minimally invasive approach with the da Vinci System (Intuitive Surgical Inc)[21] and another using the operating microscope.[9] In both studies, ansa cervicalis was identified low in the neck around the omohyoid muscle, and end-to-end anastomosis was created with 8-0 monofilament in the first case and 10-0 nylon sutures in the other. An entire ansa was used in both studies and was believed to provide the best size match for the RLN.[9,21] At the time of surgery, most authors also performed a temporary injection laryngoplasty of the paralyzed vocal cord.

The results of laryngeal innervation were documented during a follow-up period that ranged from 3 months to 6 years. Many authors used validated subjective measures to assess the quality of voice and its effect on the child's life, including the Pediatric Voice-Related Quality of Life, Voice Handicap Index, and Consensus Auditory-Perceptual Evaluation of Voice, along with objective measures of voice, such as maximum phonation time and pitch range. Most studies did not collect preoperative voice data and instead relied solely on postoperative results to demonstrate the effect of the reinnervation on voice. Nevertheless, all the authors commented that reinnervation improved or resolved the dysphonia in children with UVCP. In the largest cohort of pediatric patients, Smith et al[24] found that ansa-RLN reinnervation led to a statistically significant improvement in mean parental global voice rating and GRBAS (grade, roughness, breathiness, asthenia, and strain) rating scale compared with preoperative data. In the same study,[24] the authors found that the mean parental assessment of dysphasia improved from 3.7 to 1.4 (P = .05). The other studies did not investigate the effect of reinnervation on dysphagia. Of 36 patients, one had a complication that was related to surgery: development of a hypertrophic neck scar.[24]

A few authors commented on the length of time from surgery to improvement in symptoms. Tucker[13] reported improvement or resolution of symptoms at 3 months postoperatively in all 3 of his patients. Sipp et al[16] reported that one patient improved at 3 months

Table 2. Studies Reporting on Thyroplasty for Pediatric UVCP

Source (No. of Patients)	Level of Evidence/ Risk of Bias	Age, y	UVCP Origin	Time to Surgery, y	Indication	Anesthesia or Airway Management	Results			Adverse Events
							Dysphonia	Swallow	Glottic Closure	
Isaacson,[18] 1990 (1)	4/5	14	Neurologic	10	Aphonia and aspiration	GA tracheostomy	Deteriorated at 6 mo	Deteriorated at 6 mo	Increase in glottic gap at 6 mo	None
Link et al,[19] 1999 (6)	4/5	17	Idiopathic	NA	Dysphonia	Local	Resolved	NA	NA	NA
		14	Congenital		Dysphonia	Local	Improvement	NA		
		12	Cardiac surgery		Dysphonia and aspiration	GA	No improvement	Improvement		
		14	Skull base tumor			Local	No improvement	Improvement		
		14	Skull base tumor			GA	No improvement	Improvement		
		2	Cardiac surgery			GA	Resolved	Resolved		
Gardner et al,[20] 2000 (2)	4/5	8	Thoracic surgery	6.5	Dysphonia and aspiration	LMA	Improvement	Resolved	NA	None
		4	PDA ligation	4	Dysphonia	LMA	Improvement	NA	Full closure	None
Daya et al,[1] 2000 (1)	4/5	3	Tracheo-esophageal fistula repair	NA	Dysphonia	NA	No improvement	NA	NA	NA
Sipp et al,[16] 2007 (2)	4/5	5.5	Thoracic surgery	NA	Dysphonia and aspiration	LMA	NA	Resolved	NA	None
		18	Neurologic	NA	Dysphonia and aspiration	Local	NA	Resolved	NA	Aspiration pneumonia and 7 days of intubation

Abbreviations: GA, general anesthesia; LMA, laryngeal mask airway; NA, not applicable or stated; PDA, patent ductus arteriosus; UVCP, unilateral vocal cord paralysis.

and another patient improved at 5 months postoperatively. Zur[23] reported resolution of glottic closure in 7 of 7 patients examined 6 months postoperatively. Finally, Marcum et al[9] reported improvement at 7 months postoperatively. Overall, it seems that most patients will experience symptomatic improvement between 3 and 7 months.

Discussion

Our report indicates the scarcity of objective data on surgical interventions for pediatric UVCP. We found 15 English-language studies reporting information on surgical interventions in 84 patients with UVCP. This report highlights the conclusion that surgical intervention for children with UVCP is guided by level 4 evidence. In our report, 13 of 16 studies received the highest risk of bias score (Tables 1, 2, and 3). The scarcity of data is somewhat expected given that symptomatic UVCP is relatively infrequent in a pediatric population.[25]

A key issue that remains controversial in the management of UVCP is the timing of surgical intervention. In adult patients, laryngeal EMG can be used as an adjunct for prognostication and deciding on the timing of permanent intervention. Currently, there are no EMG-validated studies in pediatric patients[24]; hence, the timing of intervention should be guided by symptom severity, knowledge of UVCP natural history, and the effect of dysphonia on the child. A study of 404 children by Jabbour et al[2] provides insights into the natural history of pediatric vocal cord paralysis. The authors note that, for unilateral and bilateral vocal cord paralysis, approximately half (45.8%) of the children achieve symptomatic recovery. Significantly, both the time to symptom resolution and the rate of symptom resolution had statistically significant variations based on the vocal cord paralysis. Children with vocal cord paralysis attributable to cardiac surgery or of neurologic origin achieved lower rates of vocal cord movement recovery (24% and 27%, respectively) than children with idiopathic vocal cord paralysis (40%). In addition, children with vocal cord immobility attributable to cardiac surgery or of neurologic origin had a shorter mean time to resolution of symptoms (6.3 and 9.9 months, respectively) than the idiopathic group (11.1 months). The longest time from diagnosis to spontaneous recovery of vocal cord movement in any category of patients was 38 months.[2]

Children who experience aspiration due to UVCP should be offered at least a temporary surgical intervention, such as tracheostomy or injection medialization. However, most children with UVCP experience dysphonia as their main symptom,[2] and it is currently unclear when to offer surgery for these patients. Literature on the effect of dysphonia on children is limited. One study[8] suggests that children as young as 6 years experience concern over dysphonia. Dysphonia was found to have a negative effect on the lives of children across the domains of physical, social or functional, and emotional performance. This negative effect became more pronounced with age. Given that UVCP was mostly diagnosed close to birth in children,[2] a logical algorithm for treatment of dysphonia would consist of conservative and/or temporary measures for the first few years after diagnosis until the possibility of spontaneous recovery is minimized. After observation and ideally before 6 years of age, a more

Table 3. Studies Reporting on Reinnervation for Pediatric UVCP

Source (No. of Patients)	Level of Evidence/ Risk of Bias	Age, y	UVCP Origin (No. of Patients)	Time to Surgery, y	Indication	Procedures	Results			Adverse Events (No. of Events)
							Dysphonia	Aspiration	Glottic Closure	
Tucker,[13] 1986 (3)	4/5	Infants	NA	NA	Dysphonia	NA	Improvement	NA	Full closure	NA
Sipp et al,[16] 2007 (2)	4/5	NA	NA	NA	Dysphonia	Ansa-RLN	Resolved	NA	Full closure	NA
		NA	NA	NA	Dysphonia	Ansa-RLN	Resolved	NA	Full closure	NA
Wright and Lobe,[21] 2008 (1)	4/5	>10	Cardiac surgery	>10	Dysphonia	Ansa-RLN[a]	Improvement	NA	NA	None
Smith et al,[22] 2009 (4)	4/2	16	PDA ligation	>1	Dysphonia	AA and ansa-RLN	Improvement	NA	NA	NA
		15	Skull base tumor			AA and ansa-RLN				
		16	Skull base tumor			AA and ansa-RLN				
		12	Intubation or tonsillectomy			Ansa-RLN				
Marcum et al,[9] 2010 (1)	4/5	6	PDA ligation	6	Dysphonia	Ansa-RLN	Improvement	NA	NA	NA
Zur,[23] 2012 (10)	4/5	2-15 (median, 5.4)	PDA ligation (9) and thoracic surgery (1)	2 to 12 (median, 5.4)	Dysphonia	Ansa-RLN	Improvement in at least 7/10 patients	NA	Full closure in 7/7 tested patients	None
Smith et al,[24] 2012 (13)	4/4	2.2-8.8 (mean, 5.3)	PDA ligation (12) and coarctation of aorta repair (1)	NA	Dysphonia and aspiration	Ansa-RLN	Improvement in 9/9 patients with follow-up data	Improvement in 7/9 patients with follow-up data	NA	Hypertrophic surgical scar (1)
Seltur et al,[7] 2012 (4)	4/5	12	PDA ligation	NA	Dysphonia	Ansa-RLN	Improvement	NA	NA	NA
		10	PDA ligation							
		2	PDA ligation							
		4	Ependymoma resection							

Abbreviations: AA, arytenoid adduction; NA, not applicable or stated; PDA, patent ductus arteriosus; RLN, recurrent laryngeal nerve; UVCP, unilateral vocal cord paralysis.

[a] Transaxillary totally endoscopic robot-assisted surgery.

permanent solution to dysphonia caused by UVCP should be offered as an option to the parents.

The only surgical option for a temporary relief of UVCP symptoms is injection medialization. The duration of effect depends on the type of injectable material used. Of interest, several authors[13,16] noted that the effect of vocal cord injection appears to last longer in a pediatric population compared with the expected duration using the same materials in adults. The reasons for this phenomenon are not understood. Tucker[13] suggested that the slow relateralization of a paralyzed vocal fold as the injected material disappears may encourage gradual hyperadduction of the contralateral vocal cord. A potential concern with using injection medialization in a pediatric population is the long-term effects of repeated injections on the vocal cords as tissues grow and develop. Long-term follow-up data on vocal cord medialization are required to address this concern.

Medialization thyroplasty is the least studied surgical solution for pediatric UVCP. Only 12 cases met our inclusion criteria. The benefit of thyroplasty in children is inconsistent. In a study by Link et al,[19] 3 of 6 children with UVCP had symptomatic improvement after medialization thyroplasty. The authors attributed this result to using an adult technique on a pediatric larynx and advocated for lower placement of prosthesis to improve glottic closure. A limitation of performing thyroplasty in children compared with adults is the necessity for a general anesthetic in children. General anesthesia takes away the ability to adjust the position of prosthesis based on real-time vocal feedback. Given this limitation, several authors[16,17] have argued for the use of flexible endoscopy through a laryngeal mask airway tube during surgery to improve the positioning of the prosthesis during surgery. Another limitation of pediatric thyroplasty is the lack of long-term follow-up data. Even though the growth of pediatric larynx has been well studied,[18] it is unclear if and how often revision thyroplasties are required for a child operated on at a young age. One interesting finding that has emerged from our study is the high rate of aspiration recovery or improvement after thyroplasty (88%). Overall, it seems that thyroplasty has fallen out of favor in a pediatric population but remains a surgical option for children with aspiration, older children who might be able to tolerate procedures without anesthesia, and patients with no alternatives.

Compared with thyroplasty, reinnervation of RLN for children with UVCP should prevent the loss of muscle bulk and lead to vocal improvement irrespective of laryngeal growth. With the exception of any injectable material used for injection laryngoplasty, which is often performed concurrently with reinnervation, no foreign material is added to the larynx in reinnervation of RLN, which mini-

mizes the chance of future inflammatory reactions. Reinnervation also preserves the possibility of laryngeal framework surgery later in life. Knowledge of origin-specific rates and timing of RLN recovery has allowed surgeons to be less fearful of sacrificing any potential for recovery of RLN function with the reinnervation procedures. Several studies[7,23,24] found that reinnervation can be safe for children as young as 2 years. One study[7] reported high rates of satisfaction after reinnervation as evidenced by Pediatric Voice-Related Quality of Life scores but only a modest improvement in objective measures of voice, such as maximum phonation time. These findings highlight the need for further investigation into reinnervation outcomes in children.

Conclusions

Our report highlights the lack of quality evidence on surgical interventions for pediatric UVCP. Recent data have clarified the natural history of pediatric UVCP and helped surgeons decide when to offer interventions for UVCP. For the first few years after diagnosis of UVCP, conservative measures and/or temporary measures should be offered. The data summarized in this report suggest that injection laryngoplasty, with the exception of polytetrafluoroethylene injections, is safe, nonpermanent, and effective in children. However, long-term follow-up for children who receive the injection intervention is lacking. Thyroplasty and reinnervation are 2 long-term surgical solutions. Although thyroplasty seems to have fallen out of favor in recent years because of the difficulty of positioning the prosthesis in anesthetized pediatric patients, it is still a viable option, especially for children with aspiration. Compared with thyroplasty, reinnervation has seen a resurgence of interest. Recent studies on reinnervation techniques offer encouraging results; however, long-term follow-up data are lacking. Surgeons who offer surgical solutions for pediatric UVCP are encouraged to systematically document and present their results to further collective knowledge on management of this condition.

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