ABSTRACT

FACTORS AFFECTING AERODYNAMIC MEASUREMENT IN PEDIATRIC AIRWAY PATHOLOGIES

By Meghan Kathleen McCarthy

This study was a retrospective chart review designed to evaluate factors that impact the collection of aerodynamic data in pediatric airway patients. The study included 55 participants ranging in age from 3 years, 1 month to 16 years, 10 months, who had undergone laryngeal reconstruction procedures and had been seen at Cincinnati Children’s Hospital Center for Pediatric Voice Disorders for a complete voice evaluation. Descriptive analysis revealed that 35% (N=19) of the participants were unable to perform an aerodynamic protocol due to specific factors. These factors included issues related to mask seal, cognitive ability, cooperation, and physical ability. Descriptions of participant phonation patterns indicated that 74% of participants unable to perform aerodynamic protocol used supraglottic phonation, compared to 39% of participants able to perform the protocol. A binary logistic regression analysis indicated a significant positive correlation between participant age and ability to perform an aerodynamic protocol.
FACTORS AFFECTING AERODYNAMIC MEASUREMENT IN PEDIATRIC AIRWAY PATHOLOGIES

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CHAPTER I
Introduction and Review of the Literature

Voice Disorders in Children

A voice disorder can be described as pitch, loudness, flexibility, and/or overall voice quality that differ from persons of similar age, gender, and culture (Boyle, 2000; Stemple, Glaze, & Klaben, 2000). Children, like adults, are susceptible to a variety of vocal pathologies. It is difficult to pinpoint the actual number of children with vocal pathologies. Prevalence is reported to be between 1% and 23% in children (Wilson, 1987). Vocal pathologies are more prevalent in young boys. Typically, these children are more aggressive, gregarious voice users, often producing vocal sounds that harm the voice. Creating harmful vocal sounds and using inappropriate vocal patterns lead to voice disorders acquired secondary to vocal abuse and misuse. Other possible abusive factors contributing to acquired vocal pathologies may include yelling, throat clearing, coughing, and creating vocal noises during play.

Congenital Voice Pathologies

Children may also experience vocal defects secondary to congenital malformations of the larynx. Such disorders include vocal fold paralysis and subglottic stenosis. Vocal fold paralysis accounts for 10-20% of congenital laryngeal pathologies and is the second most common contributor to pediatric stridor (Dedo, 1979; Ungkanont, Freidman, & Suleck, 1998; Holinger, 1961). Vocal fold paralysis not only affects glottal airflow, but also negatively impacts voicing. Children born with bilateral vocal fold paralysis may require a tracheotomy to breathe or experience issues with voicing and aspiration. Medical professionals propose a variety of vocal fold paralysis etiologies including idiopathic or iatrogenic factors, neurological disorders, or possible metabolic disorders (Patel, Kerschner, & Merati, 2003). In some children, idiopathic vocal fold paralysis can resolve independently, even within the first year of life (Patel et al., 2003).

Another commonly seen congenital abnormality is subglottic stenosis, which is a narrowing of the airway below the level of the true vocal folds. This narrowing leads to stridor and overall airway compromise. Some children with subglottic stenosis are monitored during growth and do not require a tracheotomy for an established airway. However, more severe cases may lead to the placement of a tracheostomy tube and/or cricotracheal or laryngotracheal reconstruction.
Other airway anomalies can have a secondary impact on the child’s voice. Laryngomalacia, a congenital defect in which the laryngeal cartilages are flaccid, is the most common cause of stridor in the pediatric population (Olney, Greinwald, Smith, & Bauman, 1999). Many children outgrow this laryngeal airway defect with the maturation of the larynx that occurs during the first year of life; however, more severe cases will require surgical intervention (Bluestone, 2005). These children require surgery due to failure to thrive and respiratory distress, secondary to the cartilage instability or muscular weakness (Kay & Goldsmith, 2006). Children with laryngomalacia may require airway stabilization for adequate airflow to produce voice. Therefore, laryngomalacia can have a negative impact on voicing.

In some of the more severe cases of the aforementioned congenital abnormalities, surgical intervention is often required. Following these procedures, some children experience a change in vocal quality secondary to vocal fold scarring. With an increase in medical knowledge and ability to perform such intricate procedures, the ability to focus on quality of life, including post-operative voice qualities, has become more prevalent. Therefore, many voice specialists are seeing children with voice issues stemming from congenital malformations and/or post-operative scarring.

**Acquired Voice Pathologies**

**Vocal nodules.** The most frequently occurring vocal pathology among children is vocal nodules (Rahbar & Healy, 2003). Nodules in children are described as soft and flexible lesions. Size depends on the amount of time that the nodules have been present and the amount of irritation that has occurred. Nodules are bilateral lesions located at the intersection of the anterior 1/3 and posterior 2/3 of the vocal folds (Sapienza, Ruddy, & Baker, 2004). Overall, the presence of vocal nodules in the pediatric population is approximately 16.9% (Kilic, Okur, Yildirim, & Guzelsoy, 2004). Within this population, nodules are more prevalent in boys than girls (Kilic et al., 2004; Shah, Woodnorth, Glynn, & Nuss, 2005). Nodules are most often associated with voice misuse and abuse.

**Vocal fold paralysis.** Vocal fold paralysis may be acquired secondary to surgical treatment, both in the larynx and in surrounding structures, or can result from birth trauma (Patel et al., 2003). Between 21% and 49% of pediatric vocal fold paralysis is judged to be iatrogenic in nature (Patel et al.). In a related study, Rosin, Handler, Potsic, Wetmore, and Tom (1990) found that some children had multifactor causes for vocal fold paralysis; but, of the known etiologies,
neurologic, cardiac, and traumatic causes were the most prevalent. The neurologic etiology accounted for approximately 35% of the cases. These included Arnold-Chiari syndrome, central nervous system issues, and aneurism clipping surgery. Sixteen percent of the cases were cardiac in nature, with a vast majority resulting from patent ductus arteriosus surgeries. Trauma, which included intubation and birth trauma, as well as neck surgeries, accounted for approximately 22% of the cases. Only a small percentage of the etiologies were congenitally based.

Acquired vocal fold paralysis can have a negative impact on aerodigestive structures and functions within the pediatric population. Bilateral adductor vocal fold paralysis is characterized by the vocal folds paralyzed in a lateral position. The presence of an open airway often leads to aspiration potential and lack of voicing ability (Stemple et al., 2000). Children with bilateral abductor vocal fold paralysis have vocal folds paralyzed in a medial position and often require a tracheotomy or an arytenoid lateralization procedure to establish an open airway (Stemple et al.). Bilateral vocal fold paralysis has a more devastating impact on the child and his or her breathing and swallowing processes. Rosin et al. (1990) found that children with bilateral vocal fold paralysis had a greater occurrence of breathing and feeding difficulties, and required tracheotomies more frequently than children with unilateral vocal fold paralysis. Unilateral adductor vocal fold paralysis is the most common form of vocal fold paralysis and is characterized by one vocal fold paralyzed in a lateral or paramedian position (Stemple et al.). On the other hand, children with unilateral abductor vocal fold paralysis may not notice a change in voicing or airway protection. These children have one vocal fold paralyzed in a medial position. Children with unilateral abductor vocal fold paralysis may experience some stridor during exercise or other arduous activity (Stemple et al.). Rosin et al. found that children with unilateral vocal fold paralysis experienced more airway issues. It is important to plan for and create treatment plans that will address vocal fold paralysis and the resulting physical effects.

Granuloma tissue. Granuloma tissue is another acquired laryngeal issue that may occur in the pediatric population. Granuloma tissue is a fibrous collection of tissue resulting from traumatic intubation, prolonged intubation, and reflux esophagitis. Granuloma tissue can occur in the larynx at the site of an indwelling foreign object (Rahbar & Healy, 2003). Following laryngotracheal reconstruction (LTR), doctors use a stent that remains within the larynx for a specified number of weeks. The longer the stent is in place, the more probability that the child
will develop granuloma tissue as a result. Prolonged intubation also includes prolonged tracheostomy placement for the establishment of an airway. Typically, the largest population utilizing prolonged intubation is the premature, neonatal population. These children require the use of a tracheostomy tube for a patent airway. Both of these instances can lead to the development of granuloma tissue.

Reflux esophagitis can also lead to the development of granuloma tissue. In a study by Zalesska-Krecicka, Krecicki, Iwanczak, Blitek, and Horobiowska (2002), children’s reflux was rated on a scale indicating mild, moderate, or severe reflux. Of the children found to have reflux, 24% of the mild, 23% of the moderate, and 20% of the severe rated children also had granuloma formation. The presence of reflux in children can harm the delicate larynx and alter the overall morphology.

The management of granuloma tissue includes the use of voice therapy, medical management of the reflux (i.e., reflux medication), and in some cases surgical treatment (Rahbar & Healy, 2003). Granuloma tissue can create a cycle of surgical treatment due to the recurrent nature of the tissue growth following trauma to the larynx (Stemple et al., 2000). Therefore, physicians typically recommend therapy and medication and will avoid surgical intervention in most cases.

*Recurrent respiratory papillomatosis.* Juvenile onset Recurrent Respiratory Papillomatosis is aggressive; the most common abnormal laryngeal tissue growth in children (Derkay & Darrow, 2006). Papillomas appear as multifaceted, pedunculated lesions that may occur on the under surface of the vocal folds, the epiglottis, the laryngeal vestibule, other laryngeal structures, as well as the tracheal lining (Derkay & Darrow; Rahbar & Healy, 2003). Characterized by recurrent growths, it is thought that these lesions are acquired through birth exposure to the Human Papilloma Virus (Rahbar & Healy). Researchers and medical doctors have also noted the presence of recurrent respiratory papillomas in children with a history of prolonged intubation and children with gastroesophageal reflux or laryngopharyngeal reflux diagnoses (Derkay & Darrow). The presence of papilloma tissue in these populations is exacerbated by the abusive nature of their coexisting circumstances. Due to the recurrent nature of the papilloma lesions, multiple surgeries are often inevitable especially when the child’s airway is compromised by the size or quantity of the growths. When the papillomas cannot be controlled through surgical intervention or the size of the growths leads to occlusion of the
airway, often the child requires a tracheotomy to maintain an open airway (Derkay & Darrow). Therefore, close medical monitoring is necessary in this pediatric population.

*Subglottic stenosis.* Acquired subglottic stenosis has become an increasing problem within the pediatric population following the advent of prolonged intubation with ventilatory support for airway patients. Prolonged intubation leads to a narrowing of the airway lumen, and to ventilation issues in the pediatric patient. Acquired subglottic stenosis is generally more severe than the congenital form and often requires surgical intervention to provide a patent airway. Myer, O’Connor, and, Cotton (1994) introduced a grading system for subglottic stenosis. A Grade I stenosis represents any narrowing from an open lumen to 50% occlusion; Grade II is 51-70% obstruction, Grade III is 71-99% obstruction, and a Grade IV rating indicates that no detectable lumen is present. Many of the acquired stenoses are of the Grade III and IV ratings, thus illustrating the necessity of surgical intervention for adequate airway use.

Children who develop subglottic stenosis are often born prematurely and as mentioned, require prolonged intubation. The present study population has a large percentage of participants with acquired subglottic stenosis. Therefore, children with acquired subglottic stenosis are a significant population within this study.

*Laryngeal Reconstruction Procedures*

*Cricoid Split*

Other acquired voice problems may arise secondary to surgical intervention. Children often require medical intervention when the airway is compromised. The medical treatment in children with airway issues invariably includes surgical intervention. The cricoid split procedure has been considered an alternative to tracheotomy as it widens the airway to increase patency, thus avoiding the necessity of tracheostomy. Cotton (1985) described the cricoid split procedure as involving an incision through the anterior portion of the cricoid cartilage and one to two upper tracheal rings. An endotracheal tube remains in place for two weeks to serve as a stent during the healing period and extubation is attempted at the end of the two-week period. In 1985, Cotton delineated criterion for patients who may undergo the cricoid split procedure. The patient must be a young infant with the potential for future airway growth, must have adequate pulmonary reserve, and have a glottic or subglottic injury. Later, Cotton, Myer, Bratcher, and Fitton (1988) reported cricoid split procedures are used to treat children with mild to moderate subglottic stenosis and are not solely limited to use in young infants.
Laryngotracheal Reconstruction

Laryngotracheal reconstruction (LTR) is a commonly used surgery to restore airway patency in the pediatric population. Laryngotracheal reconstruction is a compilation of multiple airway procedures. The procedures can include anterior, posterior, and/or lateral cricoid cartilage splits and various types of grafts and stents (Choi & Zalzal, 1999). Proper assessment of the airway lumen allows for the determination of the appropriate procedure (Choi & Zalzal). Cotton, Myer, and O’Connor (1992) described laryngotracheal reconstruction as a five step process: (1) assessing orientation and location of the airway stenosis, (2) expansion of the airway, paying special attention to breathing, swallowing, and voicing function, (3) stabilizing the newly enlarged airway, (4) allowing time for healing, and (5) decannulation if the child had a tracheostomy in place prior to the reconstruction. Each step is important to the success of the procedure, thus errors at any step may lead to post-operative difficulty.

Laryngotracheal reconstruction can be performed as a single stage or a double stage procedure. A double staged laryngotracheal reconstruction involves the continued presence of a tracheostomy following the surgery as the larynx heals (Saunders, Thirlwall, Jacob, & Albert, 1999). Patients with more severe subglottic stenosis will need the extended stabilization time afforded by the double stage laryngotracheal reconstruction procedure (Gustafson et al., 2000). A study by Saunders et al. (1999) found that, on average, patients who underwent a double stage laryngotracheal reconstruction required more post-reconstruction procedures.

Single stage laryngotracheal reconstruction was developed to reduce the time a stent was needed, thus decreasing dependence on a tracheostomy tube (Gustafson et al., 2000). Patients who undergo a single stage laryngotracheal reconstruction have a short period of intubation that acts as a stent while the laryngeal structure heals. The procedure reduces the negative effects resulting from prolonged exposure to indwelling stents. Some negative effects may include displacement of the stent, granulation tissue, and general infection (Gustafson et al.). Children with stenosis that involves multiple sites along the length of the trachea and those with less pulmonary reserve will still need the prolonged stenting involved in double stage procedures (Gustafson et al.).

Laryngotracheal reconstruction can involve various graft sites. The severity and the location of stenosis determine which graft sites are necessary. An anterior costal cartilage graft (ACCG) is used with patients who have anterior and generally mild subglottic stenosis. A
posterior costal cartilage graft is necessary for more severe subglottic stenosis and patients with posterior subglottic stenosis (Younis, Lazar, & Astor, 2003). An anterior and posterior costal cartilage graft are performed for patients who exhibit (a) severe laryngotracheal stenosis at multiple tracheal sites, (b) total airway obstruction, (c) anterior and posterior subglottic stenosis, or, (d) circumferential subglottic stenosis (Zalzal, 1993). Patients who have undergone grafting with laryngotracheal reconstruction procedures have seen some immediate benefits. These include a decrease in scar formation, with less use of stenting, thereby decreasing morbidity and mortality associated with prolonged stenting and tracheotomy procedures (Zalzal).

**Cricotracheal Resection**

While cricoid split and some laryngotracheal reconstruction procedures are now implemented for patients with less severe subglottic stenosis (grade I or II stenosis), cricotracheal resection is recommended for patients with more severe subglottic stenosis (grades III or IV). In a study of 38 patients who had undergone a partial cricotracheal resection, Walner, Stern, and Cotton (1999) found that 1 patient was diagnosed with grade II subglottic stenosis, 27 had a grade III subglottic stenosis, and 10 had a grade IV subglottic stenosis. This study highlights the severity of subglottic stenosis served by a cricotracheal resection procedure. Cricotracheal resection began as an airway procedure performed on the adult population; however it has since been expanded to a pediatric procedure. The cricotracheal resection procedure is more involved than laryngotracheal reconstruction. Cricotracheal resection involves extensive movement and removal of a varying amount of the trachea (Hartley, Rutter, & Cotton, 2000). Therefore, it is recommended that cricotracheal resection be performed only on patients with severe airway pathologies and most laryngotracheal reconstruction should be performed on patients with moderate to mild subglottic stenosis.

Though the aforementioned procedures have been the most popular procedures, children may undergo other laryngeal surgeries that can impact the laryngeal structure, thus creating vocal pathologies. Some of the procedures may include arytenoidectomies, cordotomies, tracheoesophageal fistula repairs, tracheal dilations, laryngeal cleft repair, glottic web division, supraglottoplasties, and epiglottoplasties to name a few. Typically, laryngeal reconstruction procedures are successful in airway management; however, vocal pathologies can result in many patients.
Vocal Issues Following Surgery

Many children experience vocal quality changes following laryngeal reconstruction procedures. MacArthur, Kearns, and Healy (1994) studied patient vocal quality following surgery in 6 of 12 patients; (4 patients were aphonic and 2 did not cooperate due to age or physical disability; therefore, vocal quality could not be evaluated in these patients). Perceptually, all of the patients were judged to have a disordered voice (5 moderate-severely disordered, 1 very severely disordered). Five patients had lower fundamental frequencies relative to their age and sex.

MacArthur et al. (1994) discovered factors associated with poor voice outcome following laryngeal surgery. The factors include disrupted edge of the vocal folds, anterior commissure blunting, vocal fold paralysis, arytenoid fixation, decreased vocal fold contact, high grade stenoses, history of gastroesophageal reflux disease, prolonged intubation, prolonged stenting following laryngotracehale reconstruction, and a large number of laryngeal surgeries.

Zalzal, Loomis, Derkay, Murray, and Thomsen (1991) compared post-operative voice to pre-operative vocal quality in 16 patients. Two patients were judged to have breathy voices, 12 patients exhibited hoarseness, and 2 patients had a mixed vocal quality. Zalzal and colleagues rated severity in 15 of the 16 patients. Seven patients were judged to have a severe voice disorder, classified as noticeable 90% of the time. Five patients were rated with a moderate voice disorder, and 3 patients with a mild voice disorder.

In a more focused study, Younis et al. (2003) found that voice alteration caused long-term problems for some children who had undergone laryngotracehale reconstructions. Eight of the 46 patients who received posterior grafts during single stage laryngotracheal reconstructions were classified as having more severe voice disorders, compared to 5 of the 56 patients who had received anterior grafts only. Voice disorders were not specifically defined.

Voice disorders can occur as the result of surgical procedures to the tracheal, laryngeal areas. The potential for voice disorders increases with disturbance of the laryngeal mucosa and the possibility of scar tissue formation that can result from reconstruction procedures. However, laryngeal medical procedures are not the only etiologies for vocal pathologies.
Aerodynamic Measurement

Aerodynamic Assessment

When a child experiences a change in his or her voice relative to any of the aforementioned congenital or acquired difficulties, it is important to assess resulting vocal quality. To do so, physiologic, perceptual, acoustic, aerodynamic, and objective measures are utilized. Aerodynamic measurements are physiologic measurements of the aerodynamic aspects of voice, which include, among others, speed quotient, open quotient, maximum flow declination rate, average airflow, and subglottal pressure. The present paper will focus on aerodynamic measurements and more specifically, average airflow rates and estimated subglottic pressure. Airflow is the volume of air that passes through the larynx at a given time for a specified duration of time; estimated subglottic pressure is the pressure below the level of the vocal folds estimated by taking a measurement of intraoral air pressure during the production of a voiceless pressure consonant, such as /p/. The analysis of airflow and subglottal pressure can help discriminate between individuals with typical vocal structure and individuals who have abnormal phonation or dysphonic vocal quality (Yiu, Yuen, Whitehill, & Winkworth, 2004). Focusing on such measures as average airflow and estimated subglottal pressure can give medical professionals an indication of change in the anatomy and function of the laryngeal structure, thus gaining information about the potential pathological conditions.

Aerodynamic Equipment

In recent years, researchers in the fields of speech science, speech-language pathology, and otolaryngology have found the use of various equipment for aerodynamic measurement to be advantageous in evaluating voice disorders. Many researchers have used a combination of a circumferentially vented mask, airflow and pressure transducers, and a pneumotachograph. The circumferentially vented mask features fine wire mesh that acts as impedance for airflow. The increase in resistance causes a decrease in flow proportional to the individual’s airflow, thus airflow measures may be obtained (Sapienza, 1996). The airflow and pressure transducers then convert the aerodynamic mechanical energy into electrical energy, measurable by the pneumotachograph. The airflow signal is inverse filtered by a software program, such as CSpeech, to determine the spectral components of the airflow signal (Sapienza). Once these measures are obtained, the formants may be removed revealing the oral airflow measure (Sapienza).
Aerodynamic Protocols

Many researchers have used the same or similar protocols for aerodynamic measurement of voice. The aerodynamic protocol is structured as follows. The participant sustains /a/ for a specified amount of time. The /a/ is used for the large difference between the fundamental frequency and the first formant (Sapienza, 1996). This allows a clear distinction between the fundamental frequency and the rest of the spectrum, making it easier to examine the oral airflow measure. Then, the participant produces a train of /pa/ syllable repetitions. The participant is asked to complete an average of 5 repetitions within the same breath. The /p/ is chosen for its pressure components. The open glottis and closed lips, during production, simulate the pressure that builds below the level of the true vocal folds. Thus, the /p/ allows researchers to estimate the subglottal pressure production during speech through the measurement of intraoral pressure.

The aforementioned measures were obtained from the children with simple instructions, such as the following: “You are going to wear a mask like a diver or a pilot. I will hold it over your nose and mouth and you will breathe as you are doing now. I will ask you to say /a/ and I will raise my five fingers one at a time before asking you to take a breath. Let’s practice.” “Next, I will ask you to say a longer /a/ and close your lips each time I raise my fingers. It will sound like /paaapaaapaaapaaapaaapaaa/. Let’s practice.” Though the instructions are not complex, the nature of the influence on a young child is not known.

A tight seal between the mask and the participant’s face is essential to gaining reliable measures of airflow and pressure. A leak secondary to inadequate mask fit would mimic a high-pass filter, thus impacting airflow measures (Holmberg, Hillman, Perkell, & Gress, 1994). A leak could impact amplitude-based flow measures, such as DC flow, and subsequently all measures gained in relation to amplitude-based measurements (Holmberg et al., 1994). Though a high DC min value would result from an air leak at the level of the glottis indicating a possible pathology, an air leak around the mask would yield a very low, sometimes negative DC min value (Holmberg, Hillman, & Perkell, 1989; Holmberg et al., 1994). Sapienza (1996) found that minimum glottal airflow measures can become negative when a mask leak is present. Because the preamplifier adds -5 to +5 L/s to the signal, the value is sometimes pushed below zero.

Reliability of Measures

In order to use aerodynamic measures effectively, assessing the accuracy and reliability of the measures is imperative. A study by Yiu et al. (2004) looked at the reliability of
aerodynamic measures in 20 to 50-year-old females with dysphonic vocal qualities. Participants were asked to hold the mask for the evaluation and were instructed to exhale prior to assessment to rule out the possibility of mask air leak. Results indicated that participants with dysphonia presented with significantly higher airflow rates and subglottal pressures. Researchers were able to accurately categorize participants as dysphonic or non-dysphonic in a majority of cases, when using airflow and pressure measurements as categorization guidelines. When the participants completed 5 trials of the task, the researchers were 91.1% accurate; whereas, when only one task was attempted, researchers classified participants with 83.9% accuracy. Conclusively, aerodynamic measures were reliable in assessing voice when patients complete multiple-trial tasks.

Hartl et al. (2003) conducted a study on objective measures of breathiness in adult males with unilateral vocal fold paralysis. Patients and control participants completed a prolonged /a/ task, as well as read a phonetically balanced passage. Three speech-language pathologists and three otolaryngologists perceptually judged the grade of dysphonia, roughness, breathiness, asthenia, and strain of participants’ voices, as well as recorded acoustic and aerodynamic measures. Results showed a significant difference between the patients with unilateral vocal fold paralysis and the control group. Ten of the 14 objective measures successfully distinguished participants with unilateral vocal fold paralysis from the control group participants. Hartl et al. confirmed that objective measures can be used to reliably distinguish patients with voice disorders from patients with normal vocal quality; however, they suggested using a variety of measures.

Holmberg, Doyle, Perkell, Hammarberg, and Hillman (2003) studied 10 men with bilateral vocal nodules. Participants ranged in age from 19 to 35 years old. All participants underwent both aerodynamic and acoustic analysis. Holmberg et al. stated that aerodynamic measures indicated the existence of vocal pathologies more effectively than the acoustic measures. Thus, aerodynamic assessment was a reliable tool and may be used to evaluate and detect the presence of vocal pathologies.

*Cognition and following instructions.* In establishing reliability of measurement, it is imperative to assess the ability of the children to comprehend and follow directions. Pickering, Gathercole, and Peaker (1998) found that accurate recall of given information was greater in children 8 years of age compared to 5-year-old participants. Cowan, Nugent, Elliott, Ponomarev,
and Saults (1998) also found that older children were able to recall information at a faster rate than their younger counterparts. Recall information has the ability to provide insight into the child’s ability to listen to, process, and understand information; then complete a given task. Both studies express that older children are better equipped to complete recall tasks with accuracy and speed.

Engle, Carullo, and Collins (1991) studied the effects of memory capacity on the performance of higher-level tasks in first, third, and sixth grade children. The study found that significant correlations exist between participant performance on comprehension tasks and their performance on following direction tasks. Engle et al. (1991) reported the importance of minimizing important task directions to 3 or 4 artifacts of knowledge for a single directive. Children rely heavily on phonological cues when listening to and processing auditory information. Therefore, Engle and colleagues stressed the importance of providing information that is not phonologically confusing in order to allow for maximal direction-following potential.

In a similar study, Willis and Gathercole (2001) evaluated repetition and comprehension accuracy in 4 and 5-year-old children. They found that accuracy was greater when sentences were shorter, were reversible in nature, and included “in” or “on” clauses as opposed to “above” or “below” clauses. Willis and Gathercole concluded that these results reflected the developmental stage of syntactic abilities. Therefore, skills such as repetition and comprehension of sentences involving embedded clauses and spatial verbs develop later in the children’s repertoire. Willis and Gathercole suggested that children with good phonological short-term memory are better able to accurately repeat sentences than children with poor phonological skills. Furthermore, children need syntactic skills in order to accurately comprehend and repeat information.

When assessing the collection of aerodynamic data, many factors have an impact on the data. The child’s cognitive abilities may be one of the factors that impacts valid data collection. Therefore, knowing the child’s cognitive ability level provides essential information about his or her ability to follow instructions, and thus complete aerodynamic protocols.

Effect of Pathology on Aerodynamic Measures

Pathological conditions of the larynx often alter the structure and function of the organ. The degree of change can be measured through the use of endoscopy with or without stroboscopic visualization, perceptual, acoustic, and aerodynamic measures. Yiu et al. (2004)
studied the effects of dysphonic voice on aerodynamic measures in 28 females with vocal pathologies and 28 females without vocal pathologies. Each participant was instructed to perform four speech measurement tasks into a Rothenberg mask. Tasks included a maximum sustained vowel production, a 5-second sustained vowel production, a vowel-consonant string production, and sentence productions. Aerodynamic measures were analyzed during these tasks. Mean airflow rates for the non-dysphonic group were measured at 0.10 L/s and 0.11 L/s for maximum and comfortable intensity respectively. The dysphonic group displayed mean airflow measures that ranged from 0.16 to 0.18 L/s. Mean subglottal pressures for the dysphonic group were measured at 10.93 cmH₂O, whereas the mean non-dysphonic group measure was 7.21 cmH₂O. The dysphonic group exhibited increased airflow and subglottal pressure measures. Results correlate with expected results from patients exhibiting a lack of glottal closure during phonation.

Hartl, Hans, Vaissiere, and Brasnu (2003) investigated paralytic dysphonia through the use of acoustic and aerodynamic measures. Participants included 8 adult patients with unilateral vocal fold paralysis and 12 adults without unilateral vocal fold paralysis. However, patients without unilateral vocal fold paralysis were diagnosed with pulmonary carcinoma. Hartl et al. (2003) found that average airflow measures for patients with unilateral vocal fold paralysis were higher than measures of controls by two standard deviations. The results indicated that patients with unilateral vocal fold paralysis have greater airflow during phonation due to their compromised laryngeal mechanism. The results of the study by Hartl et al. correspond to the results obtained by Yiu et al. (2004). Those with certain vocal pathologies exhibit greater flow through the vocal folds during phonation than their peers with typical, non-disordered vocal folds.

In 1994, Sapienza and Stathopoulos studied children and women with bilateral vocal fold nodules. Participants included 8 children and 10 women with bilateral vocal fold nodules, as well as 8 children and 10 women with normal laryngeal anatomy and physiology. Women with bilateral vocal fold nodules produced a mean glottal airflow measure of 0.223 L/s and mean tracheal pressure measures at 8.05 cmH₂O for comfortable intensity and 11.56 cmH₂O for loud intensity. Adult female controls produced a mean glottal airflow measure of 0.147 L/s and mean tracheal pressure measures of 6.07 cmH₂O for comfortable intensity and 7.67 cmH₂O for loud intensity. Children with bilateral vocal fold nodules exhibited a mean glottal airflow measure of
0.161 L/s and mean tracheal pressures measured at 10.84 cmH2O for comfortable intensity and 16.29 cmH2O for loud intensity. Child controls produced a mean airflow measure of 0.139 L/s and mean tracheal pressure measures of 11.15 cmH2O for comfortable intensity and 15.75 cmH2O for loud intensity. Glottal airflow and tracheal pressure measures were generally higher for those with vocal fold nodules than the control population. Thus, those with disordered voices have abnormally high airflow and pressure measures. These results correspond to results obtained by Yiu et al. (2004), as well as Hartl et al. (2002).

Vocal pathologies in adults and children affect the physiology of the mechanism, therefore affecting aerodynamic measurements. As noted from past research, airflow measures are often increased (Sapienza & Stathopoulos, 1994; Hartl et al., 2002; Yiu et al., 2004). Estimated subglottal pressure measures are often decreased with an inability to approximate the vocal folds, but increased with hyperfunction (Sapienza & Stathopoulos). The measures correspond to a decreased ability of the vocal folds to adduct as a result of paralysis, nodules, or other congenital or acquired pathology.

**Normative Data**

Few studies have assessed aerodynamic measures in the pediatric population, however many studies have been conducted with adult participants. Data from adult studies may lend important information to studies involving children. Holmberg, Hillman, and Perkell (1988, 1989) conducted two studies on glottal airflow and transglottal pressures in male and female adults. The studies included 45 participants (25 males; 20 females). All participants were nonsmokers; had no professional speaking, singing, or voice training; were American English speakers; and, ranged in age from 17 to 30 years for males and 18 to 36 years for females. Results from the 1988 study ascertained that normal loudness and pitch yield estimated subglottal pressure that ranged from 4.4 to 9.6 cmH2O. The estimated subglottal pressure measures established during the study correlate with the 5 to 10 cmH2O subglottal pressure measures that have been confirmed through past studies. Airflow measures were found to be within previously established findings, 0.07 to 0.20 L/s. Holmberg et al. (1998) found that average airflow measures were significantly higher for males than for females within all loudness conditions.

Holmberg et al. (1989) found that air pressure measures were higher for males than for females in all pitch conditions. They also found that men exhibited higher sound pressure level
decibel levels. When this was factored out, no significant difference between the pressure measures for men and women was evident. Men were found to have higher average airflow measures within normal pitch conditions, but no significant differences were found between the male and female measures in other pitch conditions.

Stathopoulos and Sapienza (1993) studied respiratory and laryngeal measures in both children and adults. Participants included twenty 4-year-olds, twenty 8-year-olds, and twenty adults. All participants were healthy, American-English speaking, had normal hearing, with no professional voice, speech, or singing training. Results indicated that there was a significant increase in estimated subglottal pressure between loudness conditions for the children, but only from soft to loud for the adults. Also, significantly higher tracheal pressure was noted in comfortable and loud measures for children than for adults. Possible explanations for this finding point to the difference in vocal tract size and surface area between the two groups. Measures for the children indicated that there was no significant difference between airflow values in boys and girls. Results indicated that a significant difference did exist between the airflow measures of men and women. Men were noted to have significantly higher airflow measures.

Minimal research exists that evaluates aerodynamic parameters in the pediatric population. In 2005, Weinrich, Salz, and Hughes performed a normative study detailing aerodynamic measurements in children ages 6 years to 10 years, 11 months. Weinrich and colleagues stated that it is essential to compare aerodynamic parameters in the pediatric population to normative data collected from children, rather than to compare pediatric aerodynamic measures to adult data. Weinrich et al. found that mean subglottal pressure in this population ranged from 8.72 to 9.86 cmH₂O in low to high frequencies respectively. Subglottic pressure was found to decrease with age, and pressure measures were slightly lower for females than for males. The differences were not significant. Weinrich et al. established that children without voice disorders can follow adult aerodynamic protocols; however, the question still remains whether children with voice disorders can yield reliable aerodynamic voice measures. Clinicians and researchers alike must consider whether the same principles of adult assessment may be applied to the pediatric population with voice disorders.

Summary

Multiple factors have an impact on the collection of aerodynamic data in the pediatric population. The factors include the age of the child, size and structure of the child’s face, the
cognitive ability of the child, the phonation patterns, as well as types of laryngeal surgeries performed on the child. The extensive number of factors necessitates the need to evaluate the relationships between the factors and the child’s ability to produce aerodynamic data. The results obtained from the analysis can yield important information on the collection of valid and reliable aerodynamic measures in the pediatric population.

**Purpose**

The purpose of the present study was twofold:

1. to determine the characteristics of pediatric patients, post-airway reconstruction, who were unable to perform an aerodynamic protocol;
2. to evaluate the relationship between participant age and the ability to obtain aerodynamic measures.

**Research Questions**

The present study sought to answer the following questions:

1. What was the percentage of participants who were able to perform an aerodynamic protocol versus those who were unable?
   a. What were the age range and mean age for participants who were able to perform an aerodynamic protocol versus those who were unable?
2. What were the characteristics of participants unable to perform an aerodynamic protocol?
   a. What were the age range, mean age, and percentage of participants unable to perform an aerodynamic protocol due to insufficient mask seal?
   b. What were the age range, mean age, and percentage of participants unable to perform an aerodynamic protocol due to cognitive ability issues?
   c. What were the age range, mean age, and percentage of participants who were unable to perform an aerodynamic protocol due to cooperation issues?
   d. What were the age range, mean age, and percentage of participants who were unable to perform an aerodynamic protocol due to an inability to physically perform the protocol?
   e. What were the phonation patterns of participants who were unable to perform an aerodynamic protocol?
   f. What were the laryngeal surgery types of participants who were unable to perform an aerodynamic protocol?
3. Was there a significant positive correlation between participants’ age and ability to perform an aerodynamic protocol?

Research Hypothesis

1. There will be a significant positive correlation between participants’ age and ability to perform an aerodynamic protocol.
CHAPTER II
Methods

Participants

All participants were selected from existing medical records of patients seen for complete voice evaluations at Cincinnati Children’s Hospital Medical Center (CCHMC) in the Center for Pediatric Voice Disorders, Cincinnati, Ohio, between May 2005 and March 2007. A total of 100 patient charts were reviewed. Of the 100 charts, 45 patient charts were excluded from the study due to medical diagnoses (airway patients with vocal fold paralysis who were not surgical reconstruction candidates), surgical management (patients who had not undergone laryngeal reconstruction procedures prior to voice evaluation), and no aerodynamic data due to equipment error. The remaining 55 participants (24 males; 31 females) had a mean age of 8 years, 10 months (range = 3:1 to 16:10 years; SD = 3.90). The 55 participant charts were analyzed to answer the research questions. Informed consent was obtained from all participants’ caregiver(s) to use their voice evaluation data for research purposes.

Inclusion Criteria

Inclusion criteria specified that participants were between the ages of 3:0 and 17:11 years, had laryngeal airway disorders, and had previously undergone surgical airway procedures (cricoid split, cricotracheal resection, or laryngotracheal reconstruction). Prominent primary diagnoses included, but were not limited to, subglottic stenosis, trauma/prolonged intubation, vocal fold paralysis, idiopathic injuries, status post-cardiac surgery, various syndromes, and premature birth/prolonged intubation. Participants must have had two of three average airflow and estimated subglottic pressure measures within a 4% range, or an explanation must have been noted for a lack of aerodynamic data.

Exclusion Criteria

Participants were excluded from the present study if they had a laryngeal diagnosis other than an airway disorder. For example, a patient, who received a diagnosis of vocal fold nodules without an airway diagnosis of subglottic stenosis, was not included in the study. Participants were also excluded from the study, if they had not yet undergone a laryngeal airway, surgical procedure. Patient charts were excluded if aerodynamic data was unavailable due to equipment error or there was no explanation for lack of measures.
Procedure

The present study was a retrospective chart review. Medical charts from the CCHMC Center for Pediatric Voice Disorders were used to gather participant information. All charts were reviewed to evaluate participants’ abilities to perform aerodynamic protocol in relation to their age. A descriptive analysis was completed to evaluate age range, mean age, and percentage of participants who were able versus those who were unable to complete the aerodynamic protocol. For those who were unable to complete the aerodynamic protocol, a descriptive analysis was completed to evaluate the factors adversely affecting data measurement. A descriptive analysis was performed to assess the phonation pattern and laryngeal surgery type of the participants who were unable to perform the aerodynamic protocol.

Data Collection

The following information was obtained from the medical charts for each participant in the study: age, gender, phonation pattern, most recent surgery type, whether aerodynamic measures were available, and an explanation for the lack of data if none were available.
CHAPTER III
Results

Descriptive Statistics

Descriptive data was analyzed to answer the research questions. Sixty-five percent of the participants (N = 36) were able to perform the aerodynamic protocol, whereas 35% (N = 19) were unable to perform the protocol.

Participant Age/Aerodynamic Protocol Performance

To evaluate whether age had an impact on aerodynamic protocol performance, age ranges and mean ages were established for participants who were able versus unable to perform the protocol (Figure 1). Participants who were able to perform the aerodynamic protocol had a mean age of 10 years, 1 month (range = 3:7 to 16:7 years; SD = 3.82). Participants who were unable to perform the protocol had a mean age of 7 years, 1 month (range = 3:1 to 16:10 years; SD = 3.77).

*Figure 1*: Mean age and standard deviations for the participants who were able versus unable to perform the aerodynamic protocol.

Mask Seal

Participant data was analyzed to determine the participants unable to perform the protocol due to poor mask fit. There were 7 participants (37%), who were unable to perform the aerodynamic protocol due to insufficient mask fit. Participants for whom a sufficient mask seal
could not be obtained had a mean age of 7 years, 11 months (range = 5:5 to 13:9 years; SD = 3.24).

Cognitive Ability Issues

Participant charts were analyzed to determine the percentage of participants who were unable to perform aerodynamic protocol and were diagnosed with a cognitive disability. Participants within this category had a diagnosis that included a cognitive disability, such as Down’s syndrome, or the participant’s guardian provided an indication of developmental delay or cognitive disability on the patient intake form. There were 7 participants (37%), who were unable to perform the aerodynamic protocol and were diagnosed with a cognitive disability. The participants in this category had a mean age of 7 years, 3 months (range = 3:1 to 16:10 years; SD = 2.72).

Cooperation Issues

Participant charts were examined to determine the age range, mean age, and percentage of participants who were unable to perform an aerodynamic protocol due to cooperation issues. There were 4 participants (21%), who were unable to perform the protocol due to difficulty with cooperation. Participants in this category had a mean age of 4 years, 9 months (range = 3:3 to 5:11 years; SD = 1.18).

Physically Unable

An examination of participant charts revealed 1 participant (5%) with an inability to physically perform the aerodynamic protocol. The participant was unable to produce repeated airflow measures within 4% of the mean and was unable to physically perform the protocol for the collection of estimated subglottal pressure measures. The participant was 8 years, 10 months of age.

Phonation Patterns

Participant charts were analyzed to determine the laryngeal phonation patterns of the participants who were unable to perform the aerodynamic protocol (Figure 2). As evidenced by endoscopy, there were 2 participants (10%), who used true vocal fold phonation. Supraglottic phonation was observed in 14 participants (74%). Three participants (16%) used mixed phonation.
Figure 2: Phonation patterns used by the participants who were unable to perform the aerodynamic protocol.

The three phonation pattern categories (true vocal fold phonation, supraglottic phonation, and mixed phonation or true vocal fold phonation with supraglottic compression) consisted of a variety of laryngeal structure functions.

True vocal fold phonation. Within the true vocal fold phonation category, 2 participants were unable to perform the aerodynamic protocol. One participant had unilateral true vocal fold immobility and 1 participant was classified as having true vocal fold phonation.

Supraglottic phonation. Fourteen participants within the supraglottic phonation category were unable to perform the aerodynamic protocol. One participant had lateral-medial phonation with off-level true vocal folds. Five participants had anterior-posterior phonation with no view of the true vocal folds. Three participants had lateral-medial phonation with no view of the true vocal folds. Three participants had mixed supraglottic phonation with no view of the true vocal folds. One participant had anterior-posterior phonation with bilateral true vocal fold immobility, and one participant had bilateral true vocal fold immobility with mixed supraglottic phonation.

Mixed phonation (true vocal fold phonation with supraglottic compression). Within the true vocal fold phonation with supraglottic compression category, 3 participants were unable to
perform aerodynamic protocol. One participant used true vocal fold phonation with supraglottic compression and 2 participants used true vocal fold phonation with lateral-medial compression. 

Figure 3: Number of participants in the supraglottic phonation category broken down by phonation pattern.

Laryngeal Surgeries

Participant charts were also analyzed to determine the surgical profiles of the participants who were unable to perform the aerodynamic protocol (Figure 4). Some participants had undergone multiple airway surgeries. For this study, data was entered for the most recent surgery. Four participants had undergone a cricotracheal resection. Six participants had undergone an LTR with APCCG. Two participants had undergone an LTR with PCCG. Six participants had an LTR with ACCG. One participant had undergone a cricoid split procedure.
Inferential Statistics

Regression Analysis

Data from the participant charts were analyzed to determine if a significant relationship existed between participant age and the ability to perform the aerodynamic protocol. A binary logistic regression analysis was run to investigate the impact of age on the performance of an aerodynamic protocol. An $\alpha$-level of 0.05 was established prior to the analysis. Participant ages were entered along with yes or no values corresponding to each participant’s ability to perform the aerodynamic protocol. The analysis yielded a G-statistic of $G = 7.854$ with a P-value of 0.005. It can be reported with 99.5% confidence, that age was a significant indicator of successfully performing the aerodynamic protocol. An odds ratio indicated that with each year increase in age, the likelihood of performing the aerodynamic protocol increased 1.25 times. Therefore, the results supported the research hypothesis which stated that there was a significant positive correlation between the participant’s age and ability to perform the aerodynamic protocol.
CHAPTER IV
Discussion

Factors Influencing Collection of Aerodynamic Data

The present study was undertaken to determine what factors influence the collection of valid aerodynamic data in children who have undergone laryngeal reconstruction procedures. Most research in the area of laryngeal reconstruction focuses on the specific techniques of the procedures, the effectiveness of each surgery, and the potential for post-operative decannulation or the avoidance of tracheotomy all together. As the procedures become more common, a focus on vocal health post-operatively has begun to occur. Keilmann and Bader (1995) stated that most vocal disorders are related to a change in airflow, subglottal pressure, and a diminished ability to perform vocal tasks efficiently. Therefore, it is important to evaluate factors impacting the collection of aerodynamic measures in voice evaluation. The resulting conclusions will be helpful to improving evaluation procedures for children who have previously undergone laryngeal reconstruction procedures.

Age and Ability

The results of the statistical analysis support the research hypothesis and show that there is a significant positive correlation between age and the ability to perform aerodynamic measures. As age increases, the likelihood that the child will be able to perform the aerodynamic protocol increases as well. Older children will be more capable of performing aerodynamic protocol than younger children. Descriptive data indicated that participants who were able to perform the aerodynamic protocol were, as a whole, older than the participants who were unable to perform the protocol. This is evidenced by the mean ages 10 years, 1 month for participants who could perform the aerodynamic protocol and 7 years, 1 month for participants who could not perform the protocol. Similarly, Pickering et al. (1998) found that 8-year-olds were able to recall order information more accurately than their 5-year-old matched participants. The results from Pickering et al. support the results from the present study and highlight the fact that older children are more cognitively able to remember and possibly perform a task. Gathercole (1999) conducted a study looking at the development of short-term memory and cognition. The results indicated that older children have a greater memory capacity and use less memory resources. Gathercole came to the conclusion that there is an increase in memory storage capacity and a decrease in resources necessary to support processing with an increase in age. Due to these
findings, it may be stated that older children are more capable of remembering instructions, therefore efficiently following an outlined protocol. The aforementioned results, along with the results of the present study, point to the fact that older children are more capable of performing an aerodynamic protocol.

Mask Seal

Mask fit was a factor affecting aerodynamic measurement in 7 of the 19 participants who were unable to perform the aerodynamic protocol. Three of the 7 participants were under the age of 7 years and possibly too small in facial size, thus affecting mask fit, and in turn, aerodynamic measurements. Of the 3 participants, only one had a diagnosis that would designate facial structure differences. This participant was diagnosed with Velo-Cardio-Facial syndrome (VCFS). VCFS impacts facial and cranial features including clefting of the velum, a prominent nose, excessive maxilla producing a long face, and retruded mandible (Jones, 2006). Due to these facial structure differences, it is conceivable that the participant with VCFS may have had a poor mask seal. Additionally, the remaining 4 of the 7 participants had negative DC min values, which would indicate insufficient mask seal. All 4 participants used supraglottic phonation during their evaluation.

Cognitive Ability Issues

Seven participants were unable to perform the aerodynamic protocol due to cognitive ability issues. These participants were all diagnosed with a syndrome that included cognitive disability, had a diagnosis of mental retardation, or had a global developmental delay. Participants with cognitive disabilities lacked aerodynamic data and were judged to be unable to perform the aerodynamic protocol. Children with lower cognitive abilities may not be able to follow a protocol or understand the instructions given in order to perform the protocol. Therefore, cognitive ability can be considered a factor impacting performance on aerodynamic measures.

A study by Marcus, Cooper, and Sweller (1996) that focused on understanding instructions indicated that difficulty comprehending is dependent on the amount of information that must be held in working memory. Instructions on how to perform the protocol may have taxed the abilities of the 7 participants with cognitive disabilities.
Cooperation

Four participants were unable to perform the aerodynamic protocol due to difficulty cooperating. These participants did not follow protocol instructions; therefore no valid aerodynamic data could be obtained. All participants were under the age of 6 years. It may be speculated that each participant’s difficulty with cooperation was related to immaturity or ability to maintain attention. A study by Gathercole (1999) discovered that changes in working memory within children can be attributed to an increase in attention and an increase in processing efficiency as the child increases in age. Gathercole considered the ability to maintain attention as a factor in performing a memory task. These results can be compared to the results from the present study. With this understanding, one can speculate that attention due to immaturity may have impacted the ability to perform the aerodynamic protocol.

Physical Ability

One participant was physically unable to perform the aerodynamic protocol. The participant was an 8 year, 10 month old child. Since there was only 1 participant in this category, further description of the participant’s characteristics revealed the following. This participant was a former premature infant who had been on ventilation for 3 months post-partum and had undergone numerous airway procedures. It was noted in the chart that the participant had to push excessively to produce voicing and once able to voice, was only able to produce two /pa/ productions within one breath; therefore, the productions only provide data about intraoral pressure, not estimated subglottal pressure. Due to the large number of laryngeal surgeries undergone by the participant (N=7), it can be assumed that extensive laryngeal changes had taken place, thus disallowing the participant to voice effectively. Though only 1 participant was unable to perform aerodynamic protocol due to physical ability, with a larger subject pool, the number of participants unable to perform aerodynamic protocol within this category may increase.

Phonation Patterns and Laryngeal Surgeries

Children are susceptible to a range of vocal pathologies and vocal function disorders. Some of these pathologies can be congenital and some acquired due to a trauma to the laryngeal area or purely vocal abuse and misuse. A major contributor to acquired vocal pathologies is laryngeal surgery. The five major reconstructive surgeries (cricotracheal resection;
laryngotracheal reconstruction with APCCG, PCCG, or ACCG; and, cricoid split) enumerated within the present study, can contribute to vocal difficulties post-operatively.

Within the present study, a majority of participants (14 of 19), who could not perform the aerodynamic protocol utilized supraglottic phonation at the time of their clinic visit. Laryngeal structures used by these patients varied across the group and there seemed to be no significant pattern. Fourteen of the 19 participants underwent a laryngotracheal reconstruction procedure (6 APCCG, 2 PCCG, and 6 ACCG), while 5 participants had a cricotracheal resection (CTR; N=4) or cricoid split (N=1). As stated earlier in this paper, CTR procedures are performed only on patients with severe airway pathologies. There were 9 of the total participants (N=55), who had undergone a CTR. Therefore, 44% of the participants who had more involved surgical management were unable to perform the aerodynamic measures. Fourteen of the total participants had undergone an LTR. Of all participants who had undergone an LTR, 33% were unable to perform the aerodynamic protocol.

In 1995, Bailey, Clary, Pengilly, and Albert examined vocal quality after laryngotracheal reconstruction. Results indicated that 8 of the 27 participants who had abnormal endoscopic findings utilized supraglottic phonation. Other findings included abnormal vocal fold movement, anterior blunting, and abnormalities of the subglottis. Post-operative results from the present study participants correlate to the results gained through previous research. Supraglottic phonation patterns are common and vocal fold changes often occur. Due to the view obstruction produced by the supraglottic compression within the present study, no definitive statement can be made about the function of the true vocal folds. Therefore, one may only speculate as to each participant’s specific need to use supraglottic phonation.

Conclusions

The results of this study indicate that age was a significant positive predictor of the ability to perform the aerodynamic protocol. Facial structure and/or size, as well as cognitive ability were the major contributing factors affecting the inability to perform an aerodynamic protocol. Individuals with cognitive deficits may not have the cognitive ability to follow an aerodynamic protocol. A majority of participants who were unable to perform the aerodynamic protocol utilized supraglottic phonation and had undergone a laryngotracheal reconstruction procedure versus a cricotracheal resection.
Limitations

The present study has resulted in new information regarding factors that may influence aerodynamic data collection. At present, there is a lack of research with which to compare the present study results. Though the study was conclusive regarding the relationship between age and ability to perform an aerodynamic protocol, more data should be examined to gain a more complete understanding of the factors influencing aerodynamic measurement.

The sample size for the study was somewhat small for a retrospective chart review. A larger sample size could lend to more representative data. Also, the present study was completed within a voice clinic that is world renowned for pediatric airway reconstructions. The participants may not have been a representative sample of the overall population of children who have undergone laryngeal reconstruction procedures. The present study is an initial study; therefore more research within the area of aerodynamic protocol should follow.

Implications for Future Research

With the addition of more participants, a greater vision of the factors that impact the collection of aerodynamic data may be realized. Since the present study is an initial look at factors within aerodynamic measurement, future research may build upon the present knowledge. The knowledge gained through the present study will provide useful information to researchers and clinicians who work with the pediatric airway population.

The data specifically highlights that older children will be more capable and better able to complete an aerodynamic protocol than younger children. Armed with this knowledge, future research may study factors that help younger children to complete an aerodynamic protocol. Protocols may be studied to evaluate how they could be streamlined and made easy to follow for all patients. The present research will help researchers and clinicians look at an aerodynamic protocol and note where it may be difficult for some children. The knowledge will eventually lead to more efficient collection of aerodynamic data, an essential piece to pediatric voice evaluation.
References


