Correlates of Aspiration and Lower Respiratory Tract Infection in Children

by

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Abstract

Rationale: Lower respiratory tract infections (LRTI) are a common cause of morbidity and mortality in children. Swallowing problems are also common in children. Aspiration is one outcome of swallowing dysfunction that may be a contributing factor to LRTI.

Methods: Retrospective review of children undergoing videofluoroscopic swallow study was done to identify the prevalence and correlates of aspiration and LRTI.

Results: Aspiration prevalence was 36.6%. Significant factors on univariate analysis included: developmental delay, LRTI, pneumonia, digestive tract anomalies, indigenous heritage, cough and congestion. With logistic regression, congestion and LRTI correlated with aspiration.

Prevalence of LRTI was 42%. Using univariate analysis pneumonia, aspiration and indigenous heritage were significant. With logistic regression, respiratory issues and indigenous heritage correlated with LRTI.

Conclusion: The etiology of LRTI is complex and multifactoral. Understanding the relationship between all factors is imperative given that current interventions are invasive and the untreated outcome can be progressive lung injury.

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LIST OF ABBREVIATIONS

CPA	Chronic Pulmonary Aspiration
CN	Cranial nerve
FEES	Fibreoptic endoscopic evaluation of swallowing
fMRI	Functional magnetic resonance imaging
GMFCS E & R	Gross Motor Function Classification System Expanded and Revised
LRTI	Lower respiratory tract infection
PET	Positron emission tomography
RSV	Respiratory syncytial virus
TMS	Transcranial magnetic stimulation
VFSS	Videofluoroscopic swallow study

1.0 Introduction

Feeding and breathing are complex functions that are inherent to the survival of human beings. A healthy infant is capable of breathing on its own at birth but is dependent on others for nourishment. One of the first roles of a mother is to feed her infant. The act of feeding solidifies the early bonding of parent and child and is the foundation of one of the most important set of skills humans learn. Later in life, eating together provides the child with a sense of his/her place within the family and culture. Eating and sharing food is a pleasurable experience in which all cultures engage.

Unfortunately, this daily activity can and often does go wrong in infancy and childhood. It is estimated that 25% to 45% of typically developing children and 33%-80% of children with developmental disorders experience feeding problems (Burklow, Phelps, Schultz, McConnell & Rudolph, 1998; Hawdon, Beauregard, Slattery & Kennedy, 2000; Linscheid, 2006; Reilly, Skuse & Poblete, 1996). Sullivan et al. (2000) found that 89% of a group of 268 children with severe neurological impairment needed help with feeding and 142 of the 268 (55%) regularly choked when eating. When eating goes well, it is not given a second thought; however, when problems such as choking, coughing with feeding and food refusal arise, this otherwise pleasant activity of daily living can become negative and fraught with emotion (Burklow, McGrath, Allred & Rudolph, 2002; Kedesday & Budd, 1998).

Swallowing is a dynamic process requiring integration of breathing and motor functions including the coordination of the muscles of the lips, tongue, cheeks, palate, pharynx and esophagus (Prasse & Kikano, 2009). Dysphagia is a disorder of swallowing that manifests as decreased coordination, timing and efficiency of swallowing (Arvedson

& Brodsky, 1993). When swallowing and breathing are not coordinated, food enters the lungs; this is known as aspiration. There is some evidence that aspiration and lower respiratory tract infection (LRTI) are associated but the evidence that aspiration *causes* LRTI is limited. However, because LRTI can be fatal, many of the techniques used to decrease and prevent the occurrence of LRTI have been targeted at swallowing and limitation of aspiration.

In an attempt to ensure adequate nutrition and prevent entry of food into the airway and lungs, a number of interventions may be used, ranging from non-invasive methods such as thickening liquids and modifying food texture to invasive methods such as nasogastric or gastrostomy tube feeding. Cessation of oral feeding as a result of gastrostomy tube insertion can complicate care for the child and result in the loss of this important activity of daily living shared between parent and child (Sleigh, 2005). Given the serious impact of the current interventions for feeding issues, it is important to understand the relationship between dysphagia, aspiration and LRTI in order to minimize invasive procedures whenever possible. The purpose of this study is to identify factors that may impact on feeding and their association with LRTI.

2.0 Review of the Literature

2.1 Swallowing and Dysphagia

2.1.1 Typical Swallowing

Swallowing is taken for granted as something done approximately once per minute without much conscious thought; however, it is a complex series of events whose development begins in the embryological and fetal periods continuing into early childhood (Delaney & Arvedson, 2008). The close anatomic relationship shared by the esophagus and upper airway in the pharynx requires intricate coordination when swallowing to prevent food from entering the airway (Arvedson & Brodsky, 1993). The rhythm between swallowing and breathing is precisely controlled such that when a swallow occurs, breathing must stop.

In the past, the study of swallowing in humans was difficult as the small size and close proximity of the muscles involved made study by surface electromyography (EMG) challenging. The deeper pharyngeal muscles and the intra-oral muscles were accessed by invasive measures such as needle electrodes (Ertekin & Aydogdu, 2003). However, over the past ten years, advances in imaging techniques such as transcranial magnetic stimulation (TMS), positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) have allowed researchers to investigate the neurophysiology of swallowing in humans in more depth and detail (Mistry & Hamdy, 2008).

Swallowing involves the recruitment of many neural pathways and networks including areas in the inferior precentral gyrus, the medullary brainstem and the cerebellum (Zald & Pardo, 1999). Many muscles and nerves contribute to the complex act of human swallowing. This synchrony of events requires the coordination of more

than 20 muscles innervated by five cranial nerves (CN) acting together in a two second time frame. Integrated swallowing occurs efficiently without allowing food, liquid or saliva to enter the airway (Tuchman & Walter, 1994).

The five cranial nerves that provide motor innervation to oral and pharyngeal structures are: CN V (trigeminal), CN VII (facial), CN IX (glossopharyngeal), CN X (vagus) and CN XII (hypoglossal). Cranial nerves V, IX and X carry sensory information that alters the level of muscle recruitment required, modifies the threshold needed for a pharyngeal swallow and assists in initiating a swallow (Mistry & Hamdy, 2008).

The neurophysiological control of swallowing is complex and multi-level in nature. It is hypothesized to be organized in a hierarchal manner with the brainstem-swallowing centre at the core of the system. Second and third levels of swallowing control are in subcortical structures including the basal ganglia, hypothalamus, amygdala, the tegmental area of the midbrain and the suprabulbar cortical swallowing centres (Mistry & Hamdy, 2008). Given the complex interplay required between multiple areas of the brain it is not surprising that dysphagia occurs with many different neurological conditions.

Swallowing is typically divided into three phases: oral, pharyngeal and esophageal. The oral and pharyngeal phases are intimately related but the oral phase is considered to be under voluntary control while the pharyngeal phase is considered to be reflexive.

The main functions of the oral phase are preparation of the bolus for swallowing and trigger of the swallow prior to entry of the bolus into the pharynx. The oral phase is voluntary and the duration is variable dependent on the type of food/liquid, taste, hunger

and motivation and level of consciousness of the person eating. The tongue moves the food in the mouth to allow processing by the teeth and gathering of the food/liquid into a bolus in preparation for swallowing. Sensory input from many structures in the oropharyngeal region including the tonsillar pillars, base of the tongue and oropharyngeal mucosa has been considered as important for swallow trigger. Sensory aspects regarding taste and smell also provide additional information to the cortex in preparation for the swallow (Cichero & Murdoch, 2006).

To prepare for transit of the food bolus into the pharynx, the soft palate elevates to close the nasopharynx, the larynx elevates and the vocal cords and epiglottis close the larynx to protect the airway as the bolus passes by. A normal swallow should occur between late inspiration and late expiration and there is always an apneic period during the pharyngeal phase (Ertekin & Aydogdu, 2003).

As the tongue pushes the food bolus posteriorly, the pharyngeal constrictor muscles move the bolus into the esophagus. The upper esophageal sphincter opens and the cricopharyngeus muscle relaxes to allow food into the esophagus, completing the pharyngeal phase. The upper esophageal sphincter closes to contain the esophageal and gastric contents and the bolus is propelled down the esophagus. The esophageal phase consists of a peristaltic wave of striated and smooth muscle, which moves from esophagus to the stomach (Ertekin & Aydogdu, 2003).

The final stage is described as a resting state in that all structures return to their previous positions; the cricopharyngeus contracts to close the upper esophagus, the larynx descends, the glottis opens, the palate and tongue return to resting positions. A

reflexive cough may occur if any residual food or liquid remain in the pharyngeal area (Cichero & Murdoch, 2006).

The events, as described, seem to occur in defined step-by-step actions; however in reality, the timing of the oral phase for a liquid bolus is one second, the timing of the pharyngeal phase for all textures of boluses is one second (Cichero & Murdoch, 2006), while the esophageal phase is much longer and can take more than 10 seconds in the conscious adult (Ertekin & Aydogdu, 2003).

It is imperative to consider swallowing in synchrony with breathing as the two functions occur as a type of biological time share (Selley, Flack, Ellis & Brooks, 1989) with the pharynx being the common pathway that is primarily used for respiration but also must be shared with swallowing. Embryologically, swallowing and breathing do not develop synchronously; swallowing is established much earlier in development than breathing. Swallowing is observed in the embryo at 12 weeks gestational age. Taste buds form by 7 weeks gestation and by 20 weeks sweet can be distinguished from bitter. By the end of the first trimester (12 weeks) the fetus is able to swallow, absorb and discharge amniotic fluid (Delaney & Arvedson, 2008). While swallowing is evident early on in development, coordination between breathing and swallowing is not well integrated until after 34 weeks gestational age. Newborns have a poorly developed cough reflex and respond to laryngeal irritation with a period of apnea, then a swallow, and finally perhaps a cough. By one month of age, it is estimated that 80% of infants are coughing instead of using the apneaic response (Bamford, Taciak & Gewolb, 1992).

2.1.1 Atypical Swallowing

Disturbance of any portion of the oral and pharyngeal phases of swallowing is known as dysphagia (Arvedson & Brodsky, 1993). Consequences of dysphagia can include inefficient food propulsion, incoordination of breath-swallow cycles, delayed utilization of protective airway responses and poor nutrition (Loughlin, 1989; Sullivan et al., 2000). Clinical and functional signs of dysphagia can include poor oral motor coordination when eating, respiratory distress, oxygen desaturation, wheeze, coughing, voice changes or congestion, gagging, choking and lethargy (Arvedson & Brodsky, 1993; Weir, McMahon, Barry, Masters & Chang, 2009).

Dysphagia can be caused by a range of diagnoses including neurological disorders, anatomic abnormalities, genetic conditions, conditions affecting breath swallow cycles and other co-morbidities including gastroesophageal reflux (Lefton-Greif, 2008; Mercado-Deane et al., 2001). Rommel, DeMeyer, Feenstra and Veereman-Wauters (2003) found that the root cause of feeding difficulties may be medical, oral or behavioral and may vary depending on the child's age, stage of development and medical diagnosis.

A community based survey by Reilly et al. (1996) found 90% of a sample of 49 children with cerebral palsy demonstrated oral motor dysfunction. Calis et al. (2008), in a prospective study of 166 children with cerebral palsy, found that the prevalence of dysphagia was 99%; dysphagia was positively related to severity of motor impairment.

While dysphagia, including limited ability to process and propel food, delayed or absent swallow trigger and aspiration, has commonly been identified for children with developmental impairment (Somerville et al., 2008), children with no known

developmental variation but with a history of respiratory infection have also been reported to aspirate while ill with the respiratory infection; the aspiration resolved as lung health improved (Khoshoo & Edell, 1999; Khoshoo, Ross, Kelly, Edell & Brown, 2001; Rempel, Borton & Kumar, 2006).

2.2 Aspiration

2.2.1 Definition

A significant complication of dysphagia is aspiration, which is defined as entry of fluid, food particles and/or oral secretions into the airway below the level of the true vocal folds (Weir et al., 2007). Chronic pulmonary aspiration (CPA) is defined by Boesch et al. (2006) in a review article, as the repeated passage of food material, gastric refluxate, and/or saliva into the subglottic airways in a manner sufficient to cause chronic or recurrent respiratory symptoms. CPA may be intermittent and may only occur concomitantly with other stressors such as upper respiratory tract infection.

2.2.2 Significance of Aspiration

Aspiration, on its own, may not always lead to negative health outcomes but rather will do so only in the presence of other factors (de Benedictis, Carnielli, & de Benedictis, 2009). The consequences of aspiration can include: no overt signs (known as silent aspiration); coughing when eating; wheezing; failure to thrive, repeated respiratory illness; and, in the most extreme cases, death (de Benedictis et al., 2009).

The term “aspiration lung disease” encompasses several clinical syndromes ranging from massive aspiration (usually of stomach contents) which causes significant respiratory symptoms, to chronic lung aspiration, described as repeated passage of food, gastric reflux or saliva into the airway causing chronic or recurrent symptoms (de

Benedictis et al., 2009). While small volume aspiration is common nocturnally in normal healthy people (Boesch et al., 2006) or when airway protective mechanisms are overwhelmed, impaired or bypassed (Gleeson, Eggli & Maxwell, 1997), the threshold of what constitutes pathological aspiration appears to vary among individuals.

Boesch et al. (2006) stressed the complexity of conducting research in this area, given the heterogeneity of the children affected, the variable and episodic nature of aspiration and the coexistence of various types of aspiration (due to swallowing dysfunction, reflux aspiration and salivary aspiration).

Understanding the factors that contribute to aspiration during swallowing and consequently how and if aspiration contributes to other health issues are important pieces of a complex puzzle that has significant impact on quality of life and well being. Aspiration may represent the outcome of disordered swallowing, but it is unclear how and when it contributes to more significant consequences such as chronic lung disease and LRTI.

Aspiration is seen in infants and children with feeding and swallowing problems and is commonly associated with developmental disabilities or anatomical anomalies (Arvedson, Rogers, Buck, Smart & Msall, 1994; Sullivan et al., 2000; Weiss 1988). Symptoms and conditions that may be associated with aspiration include cough, wheeze, increased frequency and duration of respiratory infections (Colombo & Hallberg, 1999; Loughlin & Lefton-Greif, 1994). Reported long term consequences of aspiration during swallowing include bronchiectasis, bronchiolitis, respiratory distress, airway obstruction, acute or recurrent pneumonia, frequent or long-lasting upper respiratory infections and

chronic lung disease (Arvedson, 1998; Colombo & Hallberg, 1999; Loughlin, 1989; Loughlin & Lefton-Greif, 1994).

2.2.3 Diagnosis of Aspiration

When aspiration is suspected, tests such as VFSS and fibreoptic endoscopic evaluation of swallowing (FEES) are used to further understand the nature and degree of dysphagia (Lefton-Greif, 2008). Ultrasonography has been applied primarily in research applications and allows for visualization of movement patterns of oral and pharyngeal structures in swallowing but it is not currently used in most clinical settings (Arvedson, 2008).

VFSS is a videotaped x-ray that provides dynamic imaging of the oral, pharyngeal and upper esophageal phases of swallowing as the child sits in the x-ray tower and consumes barium laced food and liquid. VFSS is accepted as the criterion standard for evaluating the pharyngeal and esophageal phases of swallowing that are not able to be visualized by clinical observation (Dematteo, Matovich & Hjartarson, 2005). The limitations of VFSS include: radiation exposure, a brief and somewhat unnatural simulation of a meal, and the fact that some children will be frightened and refuse to eat during the study (Arvedson, 2008; Lefton-Greif, 2008; DeMatteo et al. 2005).

The FEES was developed as an adjunct to VFSS and allows for direct visualization of the anatomy of the pharynx and larynx during swallowing. There is, however a “whiteout” period, upon initiation of the pharyngeal phase of swallowing that does not allow for observation of the entire swallow (Arvedson, 2008). The flexible endoscopic tube is inserted nasally and this can be a drawback for some children

(DeMatteo et al. 2005). Advantages include: positioning of the child is flexible, no radiation exposure and the ability to observe anatomical structures (Arvedson, 2008). VFSS and FEES are not readily available to all clinicians and there have been a limited number of reports of clinical signs of aspiration in the pediatric literature. The clinical indicators of aspiration are not fully or reliably defined to allow clinicians to diagnose aspiration. DeMatteo et al. (2005) found that cough was predictive of fluid aspiration. Weir et al. (2009) found that wet voice, wet breathing and cough were good clinical markers for aspiration of thin liquid but not for puree consistencies.

A complete assessment of dysphagia and potential aspiration is multi-factorial and requires more than a clinical observation or a VFSS to simply document aspiration. A holistic approach that considers the well being of both child and parent and the interaction and relationship between the child and parent is imperative when deciding on intervention related to dysphagia and aspiration (Arvedson, 2008; Sleigh, 2005).

2.2.4 Interventions

Medical or surgical intervention, such as repair of a cleft palate or closure of a tracheoesophageal fistula, may be used to correct anatomic abnormalities that impact on eating safely and efficiently. However many of the underlying causes of dysphagia and aspiration are due to impairments that cannot be remediated by surgery. The strategies and interventions used to deal with dysphagia and consequent aspiration may include thickening of liquids, increasing caloric density of food, food texture modification, alternate utensils or positioning at meals, cessation of oral feeding and insertion of a gastrostomy tube (Arvedson, 1998).

Cessation of oral feeding with gastrostomy tube insertion is invasive and can affect quality of life for both child and parents by complicating care and the reality of limited access to trained caregivers (Craig, Scambler & Spitz, 2003; Hazel, 2006). Mahant, Friedman, Connolly, Goia and Macarthur (2009), in a longitudinal study, found that parents of children with severe neurological impairment who were gastrostomy fed felt the tube had a positive impact on their child's health related to feeding and administration of medication but overall quality of life was not rated as improved. Therefore, it is important to understand the relationship between dysphagia, aspiration and the potential for the development of LRTI such that interventions recommended are targeted to the appropriate underlying issue and meet the needs of the child and family.

Due to a limited number of studies and the potential risk of bias in observational studies, the direct benefits of gastrostomy and jejunostomy feeding are difficult to determine given the current evidence (Sleigh & Brocklehurst, 2004). Samson-Fang, Butler and O'Donnell (2003) reviewed studies related to the effects of gastrostomy feeding and found that the designs were weak, sample sizes were small and standard definitions regarding classification of children and measurement of growth were lacking, making comparison difficult. Given the multifactoral nature of aspiration related to food texture, aspiration of oral secretions or aspiration of gastric reflux, simply removing oral feeding with the expectation that all episodes of LRTI will cease is unrealistic, and does not take into consideration the impact of removal of eating and feeding on the quality of life for the child and his/her family (Morrow, Quine, Loughlin & Craig, 2008; Sleigh, 2005).

2.3 Lower Respiratory Tract Infection

2.3.1 Definition

Lower respiratory tract infection (LRTI) may involve any or all of the intrathoracic airways, pleural space and the parenchyma of the lungs. This grouping of infections includes bronchitis, bronchiolitis and pneumonia and can be considered as LRTI (Sethi, 2010). Although most cases of LRTI are caused by microorganisms, noninfectious causes include aspiration of food or gastric acid, foreign bodies, hydrocarbons, and lipoid substances, hypersensitivity reactions, and drug- or radiation-induced pneumonitis. The causes of lung infection in neonates (Sandora & Sectish, 2011) and immunocompromised hosts are distinct from those affecting otherwise normal infants and children.

2.3.2 Mortality Data, Causes and Diagnosis

LRTI is a leading cause of morbidity and mortality in childhood (particularly among children <5 years of age) throughout the world, rivaling diarrhea as a cause of death in developing countries. With an estimated 146–159 million new episodes per year in developing countries, LRTI is estimated to cause approximately 4 million deaths among children worldwide. Currently, the incidence of community-acquired pneumonia in developed countries is estimated to be 0.026 episodes per child-year compared to 0.280 episodes per child-year in developing countries (Sandora & Sectish, 2011).

Mortality caused by pneumonia in American children declined by 97% from 1939-1996. It is hypothesized that this decline is attributable to the introduction of antibiotics, vaccines, and the expansion of medical insurance coverage for children. *Haemophilus influenzae* type b (Sandora & Sectish, 2011) was an important cause of

bacterial pneumonia in young children but has become uncommon with the routine use of effective vaccines. The introduction of heptavalent pneumococcal conjugate vaccine and its impact on pneumococcal disease has reduced the overall incidence of pneumonia in infants and children in the United States by approximately 30% in the first year of life, 20% in the second year of life, and 10% in children greater than two years of age (Sandora & Sectish, 2011).

In Canada, serious respiratory diseases such as chronic obstructive pulmonary disease and lung cancer affect over three million people; however, because data are unavailable for other conditions such as influenza, pneumonia, and bronchiolitis, the total number affected by respiratory disease is much higher and is not known (Public Health Agency of Canada, 2007). Groups at increased risk for severe lower respiratory tract infection include: extremes of age (elderly and infants), those with chronic cardio-respiratory disease or immunosuppression (disease or drug therapy) and Indigenous people (Health Canada, 2001).

The incidence of respiratory syncytial virus (RSV), which is the most common viral cause of LRTI in children under one year of age, is not collected in most Canadian provinces (Health Canada, 2001). Nunavut, the Northwest Territories and the Yukon included RSV infections in their list of reportable conditions beginning in 2000. In 2004/05, bronchiolitis and pneumonia accounted for 21% of all hospitalizations of Canadian children under 5 years of age (Public Health Agency of Canada, 2007).

Bronchiolitis caused by respiratory syncytial virus (RSV) is the most common LRTI in children under 12 months of age and is the most frequent reason for hospitalization in infants less than 6 months of age (Kovesi, Zhirong, Osborne &

Egeland, 2011; Sethi, S, 2010) and is the most common serious acute respiratory illness in infants and young children (Wheeler, 2009). It is characterized by one or more of the following: coughing, tachypnea, labored breathing, hypoxia, vomiting, irritability and poor feeding. Crackles and wheezing may be heard on chest auscultation. One to 3% of infants will require hospitalization for bronchiolitis, especially during the winter months. Bronchiolitis due to RSV infection contributes substantially to morbidity and mortality in children who have underlying medical disorders, including chronic lung disease of prematurity, cystic fibrosis, congenital heart disease, and immunodeficiency (Kerby et al., 2009).

Some of the highest rates of bronchiolitis in the world are seen in the Baffin (Qikiqtani) Region in Nunavut, Canada where the rate of hospitalization can be as high as 306 per 1000 infants during the first year of life (Banerji, 2001). This contrasts to corresponding continental United States hospitalization rates of 10 per 1000, and 53 per 1000 in developing countries (Nair et al, 2010).The cause of the high rate of LRTI in indigenous children in the Arctic is not well understood (Kovesi et al., 2011). Potential causal factors may include overcrowded homes, exposure to environmental tobacco smoke, poor ventilation in northern homes, nutritional deficiencies and oral aspiration (Kovesi et al., 2011).

Most community-acquired pneumonias in children are bacterial or viral in origin. Severity of disease, severity of fever, radiographic findings, and the characteristics of cough or lung sounds do not reliably differentiate viral from bacterial pneumonias and both may coexist. An upper respiratory infection often precedes the presentation of lower respiratory disease due to viruses. Wheezing or stridor may be prominent in viral disease

but cough, signs of respiratory difficulty and physical findings may not be different from those found in bacterial pneumonia (McKracken, 2000).

Accurate diagnosis of the child who has recurrent respiratory symptoms/infections is one of the most difficult challenges in pediatric medicine. Most children will experience one or more acute respiratory infections. The challenge is deciding when to move from treating the symptoms to performing diagnostic testing to find an underlying cause. The potential issues can range from dealing with a typical child with an upper respiratory tract infection to serious conditions such as cystic fibrosis and tuberculosis (Bush, 2009).

2.3.3 Association with Aspiration

Aspiration is a differential diagnosis for lower respiratory tract infections (Kerby et al., 2009). Difficulty with accurately identifying the etiology of a lower respiratory tract infection (McKracken, 2000) and the fact that these conditions may co-exist with or be co-contributors to the infection makes understanding the cause of the pneumonia much more challenging.

According to de Benedictis et al. (2009), there is no "gold standard" test for diagnosing chronic lung aspiration, and determining whether aspiration plays a major role in the cause of respiratory disease remains a challenge. Many questions remain regarding how much aspiration is normal at different ages, whether different types of aspiration have different outcomes and how aspiration and chronic infection may affect future lung function.

Since dysphagia predisposes to aspiration, the relationship between dysphagia and aspiration LRTI may seem obvious, but the evidence for this causal relationship is not

conclusive (Langmore et al., 1998). Taniguchi and Moyer (1994), in a retrospective chart review of 142 children who underwent VFSS, found that aspiration, gastroesophageal reflux and presence of a tracheostomy tube were significantly associated with pneumonia. However, Weir et al. (2007), also using retrospective data, found that aspiration was not predictive of pneumonia when other factors were considered. As both studies were retrospective they were limited by the quality and accuracy of information in the medical record from which their data was derived. Weir et al. used the World Health Organization criteria for diagnosis including documentation of the presence of a cough, fever, tachypnea and dyspnea. While the use of consistent criteria for pneumonia is valid, a retrospective study design remains limited in that there may have been an under-reporting of the incidence of LRTI due to omissions in the chart or inconsistently applied clinical criteria for LRTI reported in the medical record.

The long-term consequences of continued aspiration remain unknown but many lung diseases occurring in adults are thought to have begun in childhood (von Mutius, 2001). No prospective longitudinal studies were found that examined the consequences that swallowing dysfunction in infancy and childhood may potentially have later in life.

Many studies that correlate aspiration with LRTI (Burklow, McGrath, Valerius &Rudolph, 2002; Sheikh et al., 2001; Taniguchi & Moyer, 1994) used a case control design or retrospective review to report clinical outcomes; there was no intervention trial. Other reports are narrative or review articles (Loughlin, 1989; Loughlin & Lefton-Greif, 1994).

Weir, McMahon & Chang (2005), in a Cochrane Database Review, examined the effect of restricting oral water ingestion on the pulmonary status of children who

aspirated thin liquid, but found that no eligible pediatric trials existed to support limiting oral intake of water. The recommendations based on the review were that research needed to focus on impact of aspiration on the development of aspiration lung disease and also should include confounders and clinical outcomes that may contribute to respiratory disease in children.

2.4 Relationships among Dysphagia, Aspiration and LRTI

Although aspiration appears to occur in a variety of populations and has been identified as a factor in the occurrence of pneumonia, no direct causal relationship between aspiration and pneumonia has been established (Weir et al., 2007). In a four-year prospective study of adults who aspirated Langmore et al., (1998) found that "Dysphagia was concluded to be an important risk factor for aspiration pneumonia but was generally not sufficient to cause pneumonia unless other risk factors were present as well" (p. 69).

While some studies have found an association between aspiration and pneumonia, others have not found aspiration to be an independent risk factor for the occurrence of pneumonia (Delaney & Arvedson, 2008; Langmore et al., 1998; Weir et al., 2007). Due to the nature of the condition, small sample size and case control designs have been limiting factors for generalization of outcomes. The complexity of the condition under review and the lack of homogeneity of the population of children who have LRTI are also limitations of the research to date.

Colombo and Hallberg (1987), while identifying aspiration as a cause of pulmonary disease, questioned if it would be possible to differentiate clinically significant aspiration from a normal degree of sub clinical aspiration that is not associated with lung damage.

Weiss (1988) and Shapiro and Healy (1988) concluded that aspiration must be prevented in order to avoid severe pulmonary damage and a direct causal relationship between aspiration and pneumonia was assumed. Weiss (1988) suggested that, although aspiration is an important complication in a patient of any age, it might assume particular importance in the developing infant or child with dysphagia. He proposed that infants and children might lack some of the compensatory mechanisms that enable adults to protect the airway, thus making early detection and prevention of aspiration essential in order to avoid severe and possibly irreversible pulmonary morbidity.

2.5 Summary and Purpose of Research

The relationship between aspiration and LRTI is not clear and has been incompletely characterized (Weir et al, 2007, Langmore et al, 1998). Further prospective work is necessary to more fully understand the factors that contribute to LRTI. It would be unethical to expose every child who has had LRTI to radiation for a VFSS to confirm aspiration, thus the identification of clinical signs of aspiration remains important as clinical evaluation may be the only practical and ethical method to identify the presence of aspiration in children.

If aspiration can occur in conjunction with a variety of conditions including cerebral palsy and Down Syndrome, in infants who have experienced a lower respiratory tract infection, and in children with no other apparent medical or health conditions, and only some of these children and infants have LRTI temporally associated with the aspiration, when does aspiration matter? The assumption persists that if aspiration occurs then oral feeding must stop, as the child will surely suffer negative respiratory consequences, and removal of oral feeding is routinely favored as a risk reduction

strategy. However, over time in clinical settings it has been observed that there are groups of children who are dysphagic and aspirate but do not appear to develop LRTI (Clinical observation, Rempel & Borton). It may be that aspiration alone is not enough to tip the balance and be the direct cause of LRTI. If so, this calls into question the need for gastrostomy feeding and its associated complications.

The etiology of LRTI may be multi-factorial and more complex than just one root cause. Understanding the relationship between dysphagia, aspiration and LRTI is imperative. The uncertainty of this issue has significant consequences given that the interventions are invasive and the outcome, left untreated, can be progressive lung injury. The current study proposes to add to the body of knowledge related to the correlates of aspiration and LRTI and the prevalence of aspiration and LRTI in a population of children attending for videofluoroscopic swallow study.

3.0 Hypotheses and Research Questions

The objectives of the study were to identify clinical, diagnostic and health factors that correlate with aspiration and LRTI and identify the prevalence of aspiration and LRTI in a population of children undergoing a VFSS. The specific research hypotheses are:

1) Cough with feeding is predictive of aspiration.
2) Congestion with feeding is predictive of aspiration.
3) Aspiration is predictive of lower respiratory tract infection.

Associated Research Questions:

a. What are the factors that predict aspiration? Clinically it is important to have a better understanding of the constellation of variables that may need to be present for the outcome of interest to be considered significant. A child coughing when drinking may be indicative of aspiration but the aspiration is not necessarily predictive of LRTI.
b. If the hypothesis that aspiration predicts LRTI is not supported then what other factors are predictors of LRTI? Given the lack of conclusive evidence in the literature for aspiration as a single correlate of LRTI, it appears that other factors may also contribute to the occurrence of LRTI.

It is important to differentiate prediction from causality. While some of the variables may be predictive of an outcome, it is not correct to state, for example, that aspiration causes LRTI.

4.0 Methods

4.1 Design

This was a retrospective case series. The cases were those of children seen consecutively by a pediatric feeding service in a children's rehabilitation centre from January 2004 to December 2006. The children were seen for assessment regarding swallowing safety and dysphagia and subsequently went on to undergo VFSS.

4.2 Cases

All infants and children from birth to age 21 years who attended VFSS swallow studies were eligible for the study. The catchment area for the cases is a large geographic region including Manitoba, northwestern Ontario and the territory of Nunavut; there is only one center in which VFSS are performed in the region. From initial review of the swallow study schedule, 420 swallow studies were done from 2004-06 inclusive; however, some children had more than one study per year or had repeat studies in all three years, thus the final number of cases was 325 as only the first swallow study was included in this analysis. Ethical approval for the study was obtained from the University of Manitoba Health Research Ethics Board.

4.3.Procedures

4.3.1 Videofluoroscopy

Children were seen for VFSS at Children's Hospital, Health Sciences Centre, Winnipeg, Manitoba. A standardized procedure was used for the examination. The child sat in a Tumbleform Feeder Seat™ in the lateral projection in the x-ray tower and was tested with four standard consistencies of liquid and puree with added barium. Aspiration

was documented by VFSS evaluation conducted by an experienced developmental pediatrician, occupational therapist and pediatric radiologist.

4.3.2 Data Collection

Children's medical records were reviewed and relevant data was collected on a purpose built Excel spreadsheet detailing the children's age, gender, medical diagnoses and observations during the clinical feeding observation. Other variables collected included health conditions grouped by body systems similar to work by Weir et al. (2007) (See Section 5.1). A pilot study of ten charts was conducted to test the spreadsheet for clarity and ease of data entry. The decision to make most of the data fields dichotomous was chosen to reduce chance of error coding and ensure clarity when entering data.

The Gross Motor Function Classification System Expanded and Revised (GMFCS-E & R) developed by Palisano et al., (1997) (See Appendix A for complete version) was used with the subset of children with cerebral palsy as Calis et al. (2008) reported that dysphagia was positively correlated with increased motor impairment.

The GMFCS-E & R is a classification system for infants, children and youth with cerebral palsy to group these children or youth according to gross motor function. Level one represents the least limitation of the child's gross motor abilities and level five the most significant limitation. The GMFCS-E & R is widely used as a scaling system and allows for more objective and meaningful grouping of children related to level of function rather than the previously used classification of mild, moderate or severe.

As one of the outcomes of interest was to determine if aspiration correlated with LRTI, children were identified as either "yes" or "no" for aspiration as defined by the passage of food or liquid below the level of the true vocal cords on videoflouroscopic

evaluation. No other gradation of swallowing dysfunction during VFSS was obtained, as interrater variability on VFSS is lowest with aspiration. It also could be argued that by using the "end-point" of aspiration, this is the most severe marker of the many symptoms that may be indicative of dysphagia. Clinical symptoms, such as congestion and cough with eating, which may be indicators of dysphagia and subsequently aspiration, were also collected.

The records were reviewed up to the time of the VFSS. No longitudinal follow up after the VFSS was recorded in this data set. The clinical record was reviewed for the prior occurrence of pneumonia, bronchiolitis or bronchitis. These diagnoses were grouped as lower respiratory tract infections (LRTI). Because of the retrospective nature of the study and because many of the children came from remote regions and some of the illness had not occurred at our center, we relied on historical information reported in the clinical record to identify the LRTI. The diagnosis of pneumonia was recorded only if a radiographic image interpreted by a radiologist using the words "pneumonia, infiltrate or consolidation" corroborated the reported pneumonia. If pneumonia was described in the clinical record as part of the intake history but no diagnostic imaging had been performed, the illness was classified as LRTI.

Many of the children were from rural or remote areas and an x-ray may have been completed at another location and unavailable for review, thus we chose to collect report of pneumonia by parent or as indicated in the medical chart at the tertiary care centre where the child was admitted for care. As this was a retrospective review and due to the nature of the care provision in Manitoba, Nunavut and Northwestern Ontario, it was not possible to access records from all sites in which the child may have received care or first

presented with respiratory symptoms; this made collection of data such as fever, cough and x-rays at time of presentation for pneumonia impractical.

5.0 Data Analysis

5.1 Variables Used in the Analyses

Some of the variables chosen for analysis were based on the work of Weir et al. (2007) which will allow comparison of this data set to the results of their work. The coding for the majority of the categories is dichotomous.

Table 1
Variables Used in the Analysis

Variable	Definition
Diagnosis	
Developmental Delay	Documented in medical record
Cerebral Palsy	As diagnosed by physician
Gross Motor Function Classification System	Five level classification system for children with cerebral palsy based on self-initiated movement. Level one is least restricted. At level five the child is most affected in their ability to complete independent gross motor movement.
Traumatic Brain Injury	As diagnosed in the medical record
Neuromuscular	Conditions such muscular dystrophy, myotonic dystrophy
Seizures	Diagnosed by physician
Fetal Alcohol Spectrum Disorder	Diagnosed by physician
Gastroesophageal Reflux	Diagnosed by barium study
Prematurity	Number of weeks
Respiratory Issues	Includes asthma, bronchitis, bronchiolitis, wheezing, pneumonia reported or in the medical record.
Lower Respiratory Tract Infection	Pneumonia, bronchiolitis or bronchitis reported in medical record or by parent
Cardiac	Condition diagnosed by physician
Pneumonia X-ray	A radiographic image interpreted by a radiologist using the words “pneumonia, infiltrate or consolidation” corroborated the reported pneumonia.
Metabolic	Metabolic conditions as diagnosed in the medical record such as glutaric aciduria.
Down Syndrome	Genetic conditions diagnosed in medical record
Anatomic Anomalies	
Naso-oropharygeal	Reported in medical record – structural anomaly of nasal oropharyngeal area

Respiratory	Structural anomaly of respiratory tract from upper border of trachea
Digestive	Structural anomaly of digestive tract from upper esophageal sphincter
Signs During Eating	
Aspiration	Entry of fluid, food particles and/or oral secretions into the airway below the level of the true vocal folds as documented on VFSS.
Cough with feed	Coughing while eating or drinking.
Congestion after eating	Evidenced by wet sounding breathing or sounding like the child has a cold
History of choking	Airway obstruction does not include gagging.
Current Feeding Method	
Oral	Accepting all nutrition by mouth
Oral and Tube	Combination of oral and gastrostomy tube feeding
Tube	All nutrition is via gastrostomy tube
Demographics	
Indigenous Heritage[1]	Determined if the family had self-declared indigenous heritage, a treaty number denoting First Nations Status was present in the clinical record or the child's postal code identified their place of residence in a First Nations or Inuit Community, each of which have unique postal codes.
Gender	Male/Female
Age	Months
In/outpatient	At time of assessment

5.2 Descriptive Analysis

Children's ages were categorized by both mean and median. The sample was predominantly a young group, however the age range was large therefore the median was also reported to provide a more accurate representation of the typical age of the group. Other demographic and diagnostic categories were expressed as raw numbers and percentages.

[1] In Canada, indigenous children come from three groups of Aboriginal people: "Indians" (commonly referred to as First Nations), Métis and Inuit. These are three distinct peoples with "unique histories, languages, cultural practices and spiritual beliefs. From Words First An Evolving Terminology Relating to Aboriginal Peoples in Canada by Communications Branch Indian and Northern Affairs Canada September 2004 **http://www.ainc-inac.gc.ca/ap/tln-eng.asp** Retrieved July 8, 2011.

5.3 Inferential Analyses

Univariate and logistic regression analyses were used to analyze the data to determine what factors may be significantly correlated with aspiration and lower respiratory tract infection. With univariate analysis, a series of Chi-square tests was used to examine the association of the independent variables with the dependent variables of aspiration and LRTI. As the goal was to further understand the variables that may predict aspiration and LRTI, logistic regression was also used to analyze the data. Logistic regression determines how much each variable contributes to the outcome of interest and assists in building a model of relevant clinical symptoms that can guide the specific intervention or approach used (D. Staley, personal communication, June 26, 2009; Norman & Streiner, 2000).

Regression analysis provides a statistical approach for explaining which variables and to what degree they are predictive of the outcome of interest (Portney & Watkins, 1993). For example, is age, the independent or predictor variable (X), predictive of blood pressure, the dependent or criterion variable (Y)? Regression in its most basic form, linear regression, examines the correlation of two variables as described above.

Logistic regression is an extension of linear regression used when the dependent variable is binary or dichotomous (i.e. yes/no) rather than continuous for which multiple linear regression would be used. The independent or predictor variables can be either continuous or dichotomous.

"The regression equation is built in a series of steps. First each individual explanatory variable is regressed on the outcome variable. The outcome variable that explains the largest proportion of the variation is selected as the first variable to be

entered into the equation. Subsequently each remaining significant variable is then regressed jointly with the first variable. The variable that provides the largest explanatory power next to the first variable is then added as the second variable. In the third step, each remaining variable is then tried with the first two to determine which will provide the maximum explanatory power. For each step, the maximum gain in the variation that is explained is compared to the variation still unexplained. This process continues until the gain in the variation is not significantly greater than random variation. The resulting equation is the most compact possible, incorporating all real explanatory relationships" (Hassard, 1991, p.258).

Wald Test

The Wald Test was used to determine the strength of the relationship between the predictor variable and the outcome variables. The value of the Wald statistic for each significant variable in the logistic regression equation is similar to performing a univariate F-test. The larger the value of the Wald statistic, (as for the F ratio), the more significant the variable and the lower the level of probability (personal communication, Staley, D, June 25, 2009).

p Value

The criterion for statistical significance was established *a priori* as $p<0.05$. The p value is an indication of the confidence that observed results are genuine and did not occur by chance related to the inevitable random variation in the sample. By setting the p value at .05, the probability of a significant result having occurred by chance is less than 5 in 100 children or 5%. This means there is a less than 5% chance that a Type I error could occur (Hassard, 1991).

A Type I (alpha, α) error is the probability of concluding that there is a significant difference between the sample and the population when there is no real difference. A Type II (beta, β) error is the probability of concluding that there is no real difference when there in fact is one (Norman & Streiner, 2000).

It is important to balance the risk between the two types of errors, as the result of committing either may impact negatively on clinical practice, patient care and further development of knowledge in the area. Practice may be altered in response to a false conclusion that there is a significant relationship between a certain intervention and the outcome (Type I error). This may result in clients and clinicians engaging in an intervention that is ineffective and no longer using or studying more helpful interventions. On the other hand, if it is falsely concluded that the intervention under investigation does not have an effect when it really does (Type II error), there is danger that an effective intervention will be rejected and no longer investigated when in fact it may have been truly useful.

The chance of committing a Type II error is increased as the value of p is made more stringent. For example, if the p value is increased to $p<.001$, the probability that the significant result occurred by chance rises to 1 in 1000, which reduces the chance of a Type I error, however the chance of missing a real result (Type II error) is increased. A p value $<.05$, in most cases, is generally accepted as offering a reasonable degree of protection against being misled to accept results that are not significant while balancing the chance of missing results that are, in fact, significant (Hassard, 1991).

6.0 Results

The records of 325 children who underwent VFSS over a three-year period were reviewed for data analysis; 119 children (36.6%) had aspirated. The mean age of the total group was 32 months (median age 14 months; range 0.25-240 months). The mean age of the aspiration group was 30 months (median age 15 months; range 0.25-216 months). There was no significant age difference between the total group and the aspiration group (Mann Whitney U Test, p=0.960). There were 201 (61.8%) males and 124 (38.2%) females in the total group. In the aspiration group there were 76 males (63.9%) and 43 females (36.1%). Children of indigenous heritage represented 35% (113) of the total group. They were significantly younger than the total group with an average age of 26.5 months (median 15 months) (p=.000).

Table 2 shows the results of the univariate analyses of the identified variables as related to aspiration. It can be seen that 46% (55 of 119) of children who aspirated on VFSS were of indigenous heritage, this is compared to 30% (64 of 212) who aspirated and were not indigenous (chi square 10.26, p=.001). Only 28% (58 of 206) of children who did not aspirate on VFSS were indigenous. Aside from indigenous heritage, other factors significantly associated with aspiration on univariate analysis included: developmental delay (chi square 5.39, p=.02) LRTI (chi square 12.50, p=.000), pneumonia (X-ray) (chi square 7.05, p=.008), anatomic anomalies of the digestive tract (chi square 5.43, p=.02) cough (chi square 10.79, p=.001) and congestion (chi square 15.48, p=.000) (Table 2).

Table 2 Relationship of Aspiration with Health, Demographic and Clinical Factors

	Total Group N=325 (%)	Aspiration Group N=119 (%)	Non-aspiration Group N=206 (%)	P value (p<.05)
Indigenous Heritage	113 (35)	55 (46)	58 (28)	**.001**
Diagnosis[a]				
Developmental Delay	145 (45)	63 (53)	82 (40)	**.020**
Cerebral Palsy	47(15)	22 (19)	25 (12)	.084
Traumatic Brain Injury	5 (2)	1 (1)	4 (2)	.532
Neuromuscular	10 (3)	3 (3)	7 (3)	.384
Seizures	25(8)	9 (8)	16 (8)	.189
Prematurity	56 (17)	18 (15)	38 (18)	.254
Fetal Alcohol Spectrum Disorder	15 (5)	3 (2.5)	12 (6)	.165
Down Syndrome	19 (6)	8 (7)	11 (5)	.401
Metabolic	3 (1)	2 (2)	1 (0.5)	.308
Gastroesophageal Reflux	131 (40)	46 (39)	85 (41)	.392
Lower Respiratory Tract Infection	135 (42)	65 (55)	70 (34)	**.000**
Cardiac	55 (17)	22 (19)	33 (16)	.314
Pneumonia (X-ray)	96 (30)	46 (39)	50 (24)	**.008**
Anatomic Anomalies				
Naso-oropharygeal	38 (12)	16 (13)	22 (11)	.298
Respiratory	26 (8)	7 (6)	19 (9)	.187
Digestive	9 (3)	0 (0)	9 (4)	**.020**
Signs during eating				
Cough with eating	132 (41)	62 (52)	70 (34)	**.001**
Congestion with eating	109 (34)	56 (47)	53 (26)	**.000**
History of Choking	71 (22)	28 (24)	43 (21)	.624

[a] Diagnostic categories are not mutually exclusive; children may be coded in more than one category.

When the significant variables were subjected to logistic regression analysis, only congestion with eating (p = 0.000) and lower respiratory tract infection (p = 0.001) remained predictive of aspiration (Table 3). The model correctly predicted 68.5% of the cases. The Cox and Snell $R^2 = 0.106$.

Table 3
Variables associated with aspiration

Variable	B	S.E.	Wald	df	Sig.	Exp(B)
Congestion with Eating	.948	.253	14.099	1	.000	2.581
Lower Respiratory Tract Infection	.851	.245	12.059	1	.001	2.341

Of the 325 children, 135 (42%) had a history of LRTI, with 96 (30%) having radiographic evidence of pneumonia. In contrast, 67 (59%) of indigenous children had a history of LRTI and radiographic evidence of pneumonia was documented in 46% of the LRTI.

When LRTI was examined with chi-square analysis, it was significantly associated with pneumonia X-ray (p>0.000), aspiration (p>0.000) and indigenous heritage (p>0.000). Using logistic regression, respiratory issues and indigenous heritage were predictive of LRTI (Table 4). The model correctly predicted 92.2% of the cases. The Cox and Snell $R^2 = 0.606$. Aspiration did not remain significant.

Table 4
Variables Associated With Lower Respiratory Tract Infection

Variable	B	S.E.	Wald	df	Sig.	Exp(B)
Respiratory Issues	6.930	1.048	43.747	1	.0001	1023.003
Indigenous Heritage	1.425	.528	7.275	1	.007	4.160

On univariate analysis, factors associated with indigenous heritage included: aspiration (chi square 11.92, p=.003), fetal alcohol spectrum disorder (FASD) (chi square 10.312, p=.001), LRTI (chi square 22.49, p=.000), pneumonia–x-ray (chi square 22.60, p=.000) and respiratory anatomic anomalies (chi square 4.68, p=.021) (Table 5).

Table 5
Relationship of Indigenous Heritage with Health, Demographic and Clinical Factors

	Total Group N=325 (%)	Indigenous Heritage N=113 (%)	Non-Indigenous N=212 (%)	P Value (p<.05)
Aspiration	119 (37)	55 (49)	64 (30)	**.003**
Diagnosis [a]				
Developmental Delay	145 (45)	60 (53)	85 (40)	.066
Cerebral Palsy	47(15)	19 (17)	28 (13)	.527
Traumatic Brain Injury	5 (2)	2 (2)	3 (1)	.624
Neuromuscular	10 (3)	1 (1)	9 (4)	.085
Seizures	25(8)	8 (7)	17 (8)	.474
Prematurity	56 (17)	19 (17)	37 (17)	.508
Fetal Alcohol Spectrum Disorder	15 (5)	11 (10)	4 (2)	**.002**
Down Syndrome	19 (6)	6 (5)	13 (6)	.488
Metabolic	3 (1)	2 (2)	1 (0.5)	.278
Gastroesophageal Reflux	131 (40)	42 ((37)	89 (42)	.235

Lower Respiratory Tract Infection	135 (42)	67 (59)	68 (32)	**.000**
Cardiac	55 (17)	18 (16)	37 (17)	.427
Pneumonia (X-ray)	96 (30)	52 (46)	44 (21)	**.000**
Anatomic Anomalies				
Naso-oropharygeal	38 (12)	14 (12)	24 (11)	.453
Respiratory	26 (8)	4 (4)	22 (10)	**.021**
Digestive	9 (3)	4 (4)	5 (2)	.384
Signs during Eating				
Cough with eating	132 (41)	49 (43)	83 (39)	.268
Congestion with eating	109 (34)	44 (39)	65 (30)	.084
History of Choking	71 (22)	30 (27)	41 (19)	.088

With logistic regression, factors significantly associated with indigenous heritage were aspiration (p=.009), LRTI (p=. 000) and FASD (p=.000) (Table 6).

Table 6
Variables Associated with Indigenous Heritage

Variable	B	S.E.	Wald	df	Sig.	Exp(B)
Aspiration	.674	.257	6.892	1	.009	1.961
Lower Respiratory Tract Infection	1.132	.256	19.605	1	.000	3.102
Fetal Alcohol Spectrum Disorder	2.215	.619	12.818	1	.000	9.164

7.0 Discussion

7.1 Hypothesis #1: Cough with eating is predictive of aspiration.

On univariate analysis, cough with eating was found to be predictive of aspiration but it did not remain significant in the logistic regression analysis, therefore this hypothesis was not supported.

7.2 Hypothesis #2: Congestion with eating is predictive of aspiration.

Congestion during eating was found to be significant upon univariate analysis and remained so with logistic regression; the hypothesis was supported.

Weir et al. (2009) found in their retrospective review that wet voice, wet breathing and cough were significant clinical markers for aspiration of thin liquids. In contrast, data from this study showed that only congestion and lower respiratory tract infection were significantly correlated with aspiration. It should be noted that in our study no data were available for age of occurrence of first LRTI. This may be an important component as early LRTI could be associated with aspiration as the developing infant is learning to coordinate breathing and swallowing.

An increased respiratory rate such as would be associated with LRTI may, in fact, cause an infant to have difficulty coordinating breath/swallow pattern and contribute to the development of aspiration at a critical period of development (Khoshoo & Edell, 1999; Khoshoo, Ross, Kelly, Edell & Brown, 2001; Rempel et al., 2006). The constellation of events that occurs may create a "perfect storm" of a compromised respiratory system contributing to a compromised feeding and swallowing pattern resulting in aspiration which in turn may be a component in the development of further LRTI.

DeMatteo et al., (2005) examined clinical indicators of dysphagia and found that cough was the best predictor of aspiration of fluids; when other variables such as voice change, color change and delayed swallow were present, the risk of aspiration was increased. Predictors of aspiration of solids were not clinically significant. In the current study, despite that fact that 52% of children who aspirated demonstrated cough with eating, cough was not a significant variable when logistic regression was used. The increased predictive strength with the addition of other variables suggests that aspiration is not defined by a single variable and that consideration of a constellation of symptoms may provide the most robust predictive value.

In keeping with the results of other studies (Sullivan et al, 2000), the presence of a developmental disability was associated with aspiration on univariate analysis in our series; however, developmental delay did not remain significant in logistic regression. While it is well known that children with cerebral palsy have increased rates of dysphagia, this group did not aspirate significantly more than the total group at any of the GMFCS-E&R levels. This finding may have been due to the relatively small number of children in this group (47).

In the univariate analysis of correlates of aspiration, indigenous heritage was also significant. The causes for the increased occurrence of aspiration in children from this group are not immediately apparent from this study. While developmental delay was significantly correlated with aspiration in the aspiration group, developmental delay was not significantly associated with indigenous heritage or LRTI in this data set. Indigenous heritage was associated with FASD, but FASD was not correlated with either aspiration or LRTI in this sample. Thus, in this series, the presence of a developmental disability or

of FASD did not account for the increased association of aspiration in the children in the indigenous heritage group.

7.3 Hypothesis #3: Aspiration is predictive of lower respiratory tract infection.

With univariate analysis, lower respiratory tract infection was significantly associated with pneumonia X-ray ($p>0.000$), aspiration ($p>0.000$) and indigenous heritage ($p>0.000$). Upon logistic regression analysis, respiratory issues and indigenous heritage remained predictive of lower respiratory tract infection. Aspiration did not remain as a significant variable. The hypothesis was not supported.

This finding is congruent with Langmore et al.'s study (1998) that found that a grouping of factors rather than a single factor was predictive of aspiration pneumonia. They concluded that dysphagia was an important risk factor but not sufficient to cause pneumonia alone unless other risk factors were present.

Weir et al., (2007), using multivariate analysis, found that diagnoses of asthma, Down Syndrome, gastroesophageal reflux, history of LRTI, moist cough, and oxygen supplementation were associated with an increased association of pneumonia.

Consistently applied definitions of clinical symptoms and conditions are lacking, therefore terms such as 'voice change', 'congestion' and 'wet voice' may be indicative of the same clinical indicator but are defined as three different clinical signs. This could confound the grouping and coding of variables such that it appears that different variables are significant in each study.

The challenge in sorting through the impact of one variable on another is the complexity of the ongoing development of the child, the impact of age on skills and neurological maturation. The differing clusters of results in the literature lend strength to

the conclusion that there is no single variable that directly causes aspiration or pneumonia. Further prospective work is needed to understand how age, age of first episode of LRTI and health and diagnostic factors combine to create issues with swallowing and LRTI.

Indigenous Heritage

As indigenous heritage was a significant variable when reviewing both aspiration and lower respiratory tract infection, it was subjected to univariate and logistic regression analysis to further understand the potential correlates for this group of children.

Whether aspiration during swallowing is a factor related to environmental, ethnic or biological factors in indigenous children remains to be determined. However, one can speculate about several possibilities. Swallowing is a complex motor task, which is primarily reflexive in the first 3 months of life. To proceed safely, swallowing must be intricately coordinated with breathing. This is difficult when an infant is experiencing a high respiratory rate during a LRTI. Therefore, if an infant develops a LRTI early in the first year of life when swallowing skills are evolving from a largely reflexive pattern to a learned behaviour, some abnormal patterns of swallowing could be practiced and become entrained.

Support for this possibility is the observation of Khoshoo et al. (2001) that children without known risk factors for aspiration during swallowing who have acute bronchiolitis have been shown to aspirate for several weeks after resolution of their respiratory illness. We speculate that in indigenous infants who experience frequent LRTIs, aspiration may result because of challenges in timing the breaths and swallows during the LRTI. If LRTIs recur due to a host of factors that affect this group of children,

the aspiration may be perpetuated and in turn, contribute to the occurrence of subsequent LRTIs.

In addition to the high respiratory rate during an LRTI, environmental factors such as poor air quality and tobacco smoke exposure, may also contribute to the occurrence of aspiration in indigenous children. Tobacco smoke exposure can decrease the sensitivity of the trachea to aspiration, blunting the cough after an aspiration event occurs (Dua, Bardan, Ren, Sui & Shaker, 2002). Feeding practices such as bottle-feeding at night in the supine position may also contribute to aspiration, as the child may not be sufficiently awake to safely coordinate breathing and swallowing. However, all these considerations remain purely speculative at present and await a prospective review.

Indigenous children in this series who aspirated during swallowing were more likely than the other children who aspirated to have had LRTI. Several authors have demonstrated that aspiration may be a significant risk factor for LRTI only if there are other co-occurring factors (Owayed, Campbell & Wang, 2000; Weir et al, 2005). Boesch et al. (2006) have stated that the "threshold of what constitutes pathological aspiration in a given individual may vary." In a study of infants undergoing VFSS, Newman, Keckley, Petersen and Hamner (2001), demonstrated that similar numbers of infants with and without aspiration had had pneumonia. Weir et al. showed that when factors that could contribute to LRTI were controlled for, aspiration was no longer a significant correlate of LRTI. Similarly, Langmore et al. (1998) demonstrated that dependent feeding, smoking, multiple medical illnesses and dental caries were all independent correlates of pneumonia but aspiration itself was not. In the series examined in our study the significance of aspiration as a correlate of LRTI, especially in indigenous children, may be heightened

because of the occurrence of the multiple risk factors associated with LRTI that indigenous children experience.

Limitations of the Study

The retrospective nature of the data collection is a main limitation of this study. Quality of the data was reliant on the quality and consistency of data documented in the medical record. Variability in charting procedures and definitions exists that may have impacted on the information available to be retrieved.

There was also selection bias as the review included only children who were referred for evaluation of feeding and swallowing difficulty. Furthermore, data is lacking about feeding practices, smoke exposure and the timing of the first occurrence of LRTI. However, some of these challenges are offset by the large sample size and the fact that all children undergoing swallow studies in our region are assessed in a single site by a single team. Ideally, a prospective population study of randomly selected subjects would help to define the magnitude of the problem, but this must await the development of non-invasive tools for the diagnosis of aspiration.

8.0 Conclusions and Clinical Implications

The aim of this study was to ascertain correlates of aspiration and lower respiratory tract infection. Cough and congestion were associated with aspiration during swallowing on univariate analysis for all children who aspirated in this series, but only congestion after eating remained a significant factor under regression analysis. Cough with feeding has been found to be a significant predictor of aspiration during swallowing in children of various ages and diagnoses (DeMatteo et al, 2005) but silent aspiration is also not infrequent in children (Smith, Logemann, Colangelo, Rademaker, & Pauloski, 1999). This study suggests that upper airway congestion after eating or drinking may be a more consistent marker for aspiration in children.

The association between aspiration and LRTI was not confirmed in this review for the whole group. While prospective data is required to confirm the results, it appears that aspiration during swallowing is strongly associated with indigenous heritage. The cause of this association may lie in the occurrence of LRTI early in life when swallowing skills are being learned and becoming entrained.

Thus, an indigenous child who has a history of LRTI and congestion with feeding may benefit from aspiration reduction intervention, which may include the use of thickened liquids and eliminating nocturnal supine bottle-feeding rather than surgical insertion of a gastrostomy tube and cessation of oral intake. Given that other variables, such as overcrowding, environmental tobacco smoke exposure and lack of running water have been also been documented as potential contributors (Kovesi et al, 2011, Hennessy et al., 2008) it is important to consider mitigation of aspiration through non-invasive

techniques prior to moving to drastic surgical intervention that is life altering for both the child and family.

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GMFCS-E&R
Gross Motor Function Classification System Expanded and Revised

INTRODUCTION & USER INSTRUCTIONS

The Gross Motor Function Classification System (GMFCS) for cerebral palsy is based on self-initiated movement, with emphasis on sitting, transfers, and mobility. When defining a five-level classification system, our primary criterion has been that the distinctions between levels must be meaningful in daily life. Distinctions are based on functional limitations, the need for hand-held mobility devices (such as walkers, crutches, or canes) or wheeled mobility, and to a much lesser extent, quality of movement. The distinctions between Levels I and II are not as pronounced as the distinctions between the other levels, particularly for infants less than 2 years of age.

The expanded GMFCS (2007) includes an age band for youth 12 to 18 years of age and emphasizes the concepts inherent in the World Health Organization's International Classification of Functioning, Disability and Health (ICF). We encourage users to be aware of the impact that environmental and personal factors may have on what children and youth are observed or reported to do. The focus of the GMFCS is on determining which level best represents the child's or youth's present abilities and limitations in gross motor function. Emphasis is on usual performance in home, school, and community settings (i.e., what they do), rather than what they are known to be able to do at their best (capability). It is therefore important to classify current performance in gross motor function and not to include judgments about the quality of movement or prognosis for improvement.

The title for each level is the method of mobility that is most characteristic of performance after 6 years of age. The descriptions of functional abilities and limitations for each age band are broad and are not intended to describe all aspects of the function of individual children/youth. For example, an infant with hemiplegia who is unable to crawl on his or her hands and knees, but otherwise fits the description of Level I (i.e., can pull to stand and walk), would be classified in Level I. The scale is ordinal, with no intent that the distances between levels be considered equal or that children and youth with cerebral palsy are equally distributed across the five levels. A summary of the distinctions between each pair of

levels is provided to assist in determining the level that most closely resembles a child's/youth's current gross motor function.

We recognize that the manifestations of gross motor function are dependent on age, especially during infancy and early childhood. For each level, separate descriptions are provided in several age bands. Children below age 2 should be considered at their corrected age if they were premature. The descriptions for the 6 to 12 year and 12 to18 year age bands reflect the potential impact of environment factors (e.g., distances in school and community) and personal factors (e.g., energy demands and social preferences) on methods of mobility.

An effort has been made to emphasize abilities rather than limitations. Thus, as a general principle, *the* gross motor function of children and youth who are able to perform the functions described in any particular level will probably be classified at or above that level of function; in contrast, the gross motor function of children and *youth who cannot* perform the functions of a particular level should be classified below that level of function.

OPERATIONAL DEFINITIONS

Body support walker - A mobility device that supports the pelvis and trunk. The child/youth is physically positioned in the walker by another person.

Hand-held mobility device - Canes, crutches, and anterior and posterior walkers that do not support the trunk during walking.

Physical assistance - Another person manually assists the child/youth to move.

Powered mobility - The child/youth actively controls the joystick or electrical switch that enables independent mobility. The mobility base may be a wheelchair, scooter or other type of powered mobility device.

Self-propels manual wheelchair - The child/youth actively uses arms and hands or feet to propel the wheels and move.

Transported - A person manually pushes a mobility device (e.g., wheelchair, stroller, or pram) to move the child/youth from one place to another.

Walks - Unless otherwise specified indicates no physical assistance from another person or any use of a hand-held mobility device. An orthosis (i.e., brace or splint) may be worn.

Wheeled mobility - Refers to any type of device with wheels that enables movement (e.g., stroller, manual wheelchair, or powered wheelchair).

GENERAL HEADINGS FOR EACH LEVEL

LEVEL 1	Walks without Limitations
LEVEL II	Walks with Limitations
LEVEL III	Walks Using a Hand-Held Mobility Device
LEVEL IV	Self-Mobility with Limitations; May Use Powered Mobility
LEVEL V	Transported in a Manual Wheelchair

DISTINCTIONS BETWEEN LEVELS

Distinctions Between Levels I and II - Compared with children and youth in Level I, children and youth in Level II have limitations walking long distances and balancing; may need a hand-held mobility device when first learning to walk; may use wheeled mobility when traveling long distances outdoors and in the community; require the use of a railing to walk up and down stairs; and are not as capable of running and jumping.

Distinctions Between Levels II and III - Children and youth in Level II are capable of walking without a hand-held mobility device after age 4 (although they may choose to use one at times). Children and youth in Level III need a hand-held mobility device to walk indoors and use wheeled mobility outdoors and in the community.

Distinctions Between Levels III and IV - Children and youth in Level III sit on their own or require at most limited external support to sit, are more independent in standing transfers, and walk with a hand-held mobility device. Children and youth in Level IV function in sitting (usually supported) but self-mobility is limited. Children and youth in Level IV are more likely to be transported in a manual wheelchair or use powered mobility.

Distinctions Between Levels IV and V - Children and youth in Level V have severe limitations in head and trunk control and require extensive assisted technology and physical assistance. Self-mobility is achieved only if the child/youth can learn how to operate a powered wheelchair.

Gross Motor Function Classification System - Expanded and Revised (GMFCS-E&R)

LEVEL I: Infants move in and out of sitting and floor sit with both hands free to manipulate objects. Infants crawl on hands and knees, pull to stand and take steps holding on to furniture. Infants walk between 18 months and 2 years of age without the need for any assistive mobility device.
LEVEL II: Infants maintain floor sitting but may need to use their hands for support to maintain balance. Infants creep on their stomach or crawl on hands and knees. Infants may pull to stand and take steps holding on to furniture.
LEVEL III: Infants maintain floor sitting when the low back is supported. Infants roll and creep forward on their stomachs.
LEVEL IV: Infants have head control but trunk support is required for floor sitting. Infants can roll to supine and may roll to prone.
LEVEL V: Physical impairments limit voluntary control of movement. Infants are unable to maintain antigravity head and trunk postures in prone and sitting. Infants require adult assistance to roll.

BETWEEN 2ND AND 4TH BIRTHDAY

LEVEL I: Children floor sit with both hands free to manipulate objects. Movements in and out of floor sitting and standing are performed without adult assistance. Children walk as the preferred method of mobility without the need for any assistive mobility device.
LEVEL II: Children floor sit but may have difficulty with balance when both hands are free to manipulate objects. Movements in and out of sitting are performed without adult assistance. Children pull to stand on a stable surface. Children crawl on hands and knees with a reciprocal pattern, cruise holding onto furniture and walk using an assistive mobility device as preferred methods of mobility.

LEVEL III: Children maintain floor sitting often by "W-sitting" (sitting between flexed and internally rotated hips and knees) and may require adult assistance to assume sitting. Children creep on their stomach or crawl on hands and knees (often without reciprocal leg movements) as their primary methods of self-mobility. Children may pull to stand on a stable surface and cruise short distances. Children may walk short distances indoors using a hand-held mobility device (walker) and adult assistance for steering and turning.

LEVEL IV: Children floor sit when placed, but are unable to maintain alignment and balance without use of their hands for support. Children frequently require adaptive equipment for sitting and standing. Self-mobility for short distances (within a room) is achieved through rolling, creeping on stomach, or crawling on hands and knees without reciprocal leg movement.

LEVEL V: Physical impairments restrict voluntary control of movement and the ability to maintain antigravity head and trunk postures. All areas of motor function are limited. Functional limitations in sitting and standing are not fully compensated for through the use of adaptive equipment and assistive technology. At Level V, children have no means of independent movement and are transported. Some children achieve self-mobility using a powered wheelchair with extensive adaptations.

BETWEEN 4TH AND 6TH BIRTHDAY

LEVEL I: Children get into and out of, and sit in, a chair without the need for hand support. Children move from the floor and from chair sitting to standing without the need for objects for support. Children walk indoors and outdoors, and climb stairs. Emerging ability to run and jump.

LEVEL II: Children sit in a chair with both hands free to manipulate objects. Children move from the floor to standing and from chair sitting to standing but often require a stable surface to push or pull up on with their arms. Children walk without the need for a handheld mobility device indoors and for short distances on level surfaces outdoors. Children climb stairs holding onto a railing but are unable to run or jump.

LEVEL III: Children sit on a regular chair but may require pelvic or trunk support to maximize hand function. Children move in and out of chair sitting using a stable surface to push on or pull up with their arms. Children walk with a hand-held mobility device on level surfaces and climb stairs with assistance from an adult. Children frequently are transported when traveling for long distances or outdoors on uneven terrain.

LEVEL IV: Children sit on a chair but need adaptive seating for trunk control and to maximize hand function. Children move in and out of chair sitting with assistance from an adult or a stable surface to push or pull up on with their arms. Children may at best walk short distances with a walker and adult supervision but have difficulty turning and maintaining balance on uneven surfaces. Children are transported in the community. Children may achieve self-mobility using a powered wheelchair.

LEVEL V: Physical impairments restrict voluntary control of movement and the ability to maintain antigravity head and trunk postures. All areas of motor function are limited. Functional limitations in sitting and standing are not fully compensated for through the use of adaptive equipment and assistive technology. At Level V, children have no means of independent movement and are transported. Some children achieve self-mobility using a powered wheelchair with extensive adaptations.

BETWEEN 6TH AND 12TH BIRTHDAY

Level I: Children walk at home, school, outdoors, and in the community. Children are able to walk up and down curbs without physical assistance and stairs without the use of a railing. Children perform gross motor skills such as running and jumping but speed, balance, and coordination are limited. Children may participate in physical activities and sports depending on personal choices and environmental factors.

Level II: Children walk in most settings. Children may experience difficulty walking long distances and balancing on uneven terrain, inclines, in crowded areas, confined spaces or when carrying objects. Children walk up and down stairs holding onto a railing or with physical assistance if there is no railing. Outdoors and in the community, children may walk with physical assistance, a hand-held mobility device, or use wheeled mobility when traveling long distances. Children have at best only minimal ability to perform gross motor skills such as running and jumping. Limitations in performance of gross motor skills may necessitate adaptations to enable participation in physical activities and sports.

Level III: Children walk using a hand-held mobility device in most indoor settings. When seated, children may require a seat belt for pelvic alignment and balance. Sit-to-stand and floor-to-stand transfers require physical assistance of a person or support surface. When traveling long distances, children use some form of wheeled mobility. Children may walk up and down stairs holding onto a railing with supervision or physical assistance. Limitations in walking may necessitate adaptations to enable participation in physical activities and sports including self-propelling a manual wheelchair or powered mobility.

Level IV: Children use methods of mobility that require physical assistance or powered mobility in most settings. Children require adaptive seating for trunk and pelvic control and physical assistance for most transfers. At home, children use floor mobility (roll, creep, or crawl), walk short distances with physical assistance, or use powered mobility. When positioned, children may use a body support walker at home or school. At school, outdoors, and in the community, children are transported in a manual wheelchair or use powered mobility. Limitations in mobility necessitate adaptations to enable participation in physical activities and sports, including physical assistance and/or powered mobility.

Level V: Children are transported in a manual wheelchair in all settings. Children are limited in their ability to maintain antigravity head and trunk postures and control arm and leg movements. Assistive technology is used to improve head alignment, seating, standing, and and/or mobility but limitations are not fully compensated by equipment. Transfers require complete physical assistance of an adult. At home, children may move short distances on the floor or may be carried by an adult. Children may achieve self-mobility using powered mobility with extensive adaptations for seating and control access. Limitations in mobility necessitate adaptations to enable participation in physical activities and sports including physical assistance and using powered mobility.

BETWEEN 12TH AND 18TH BIRTHDAY

Level I: Youth walk at home, school, outdoors, and in the community. Youth are able to walk up and down curbs without physical assistance and stairs without the use of a railing. Youth perform gross motor skills such as running and jumping but speed, balance, and coordination are limited. Youth may participate in physical activities and sports depending on personal choices and environmental factors.

Level II: Youth walk in most settings. Environmental factors (such as uneven terrain, inclines, long distances, time demands, weather, and peer acceptability) and personal preference influence mobility choices. At school or work, youth may walk using a handheld mobility device for safety. Outdoors and in the community, youth may use wheeled mobility when traveling long distances. Youth walk up and down stairs holding a railing or with physical assistance if there is no railing. Limitations in performance of gross motor skills may necessitate adaptations to enable participation in physical activities and sports.

Level III: Youth are capable of walking using a hand-held mobility device. Compared to individuals in other levels, youth in Level III demonstrate more variability in methods of mobility depending on physical ability and environmental and personal factors. When seated, youth may require a seat belt for pelvic alignment and balance. Sit-to-stand and floor-to-stand transfers require physical assistance from a person or support surface. At school, youth may self-propel a manual wheelchair or use powered mobility. Outdoors and in the community, youth are transported in a wheelchair or use powered mobility. Youth may walk up and down stairs holding onto a railing with supervision or physical assistance. Limitations in walking may necessitate adaptations to enable participation in physical activities and sports including self-propelling a manual wheelchair or powered mobility.

Level IV: Youth use wheeled mobility in most settings. Youth require adaptive seating for pelvic and trunk control. Physical assistance from 1 or 2 persons is required for transfers. Youth may support weight with their legs to assist with standing transfers. Indoors, youth may walk short distances with physical assistance, use wheeled mobility, or, when positioned, use a body support walker. Youth are physically capable of operating a powered wheelchair. When a powered wheelchair is not feasible or available, youth are transported in a manual wheelchair. Limitations in mobility necessitate adaptations to enable participation in physical activities and sports, including physical assistance and/or powered mobility.

Level V: Youth are transported in a manual wheelchair in all settings. Youth are limited in their ability to maintain antigravity head and trunk postures and control arm and leg movements. Assistive technology is used to improve head alignment, seating, standing, and mobility but limitations are not fully compensated by equipment. Physical assistance from 1 or 2 persons or a mechanical lift is required for transfers. Youth may achieve self-mobility using powered mobility with extensive adaptations for seating and control access. Limitations in mobility necessitate adaptations to enable participation in physical activities and sports including physical assistance and using powered mobility.

Appendix B: Logistic Regression Predictors of Aspiration

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	321	98.8
	Missing Cases	4	1.2
	Total	325	100.0
Unselected Cases		0	.0
Total		325	100.0

a. if weight is in effect, see classification table for the total number of cases.

Dependent Variable Encoding

Original Value	Internal Value
0	0
1	1

Block 0: Beginning Block

Classification Table[a,b]

Observed			Predicted		
			Aspiration		Percentage Correct
			0	1	
Step 0	Aspiration	0	202	0	100.0
		1	119	0	.0
	Overall Percentage				62.9

a. Constant is included in the model.

b. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 0	Constant	-.529	.116	20.967	1	.000	.589

Classification Table[a]

Observed			Predicted		
			Aspiration		Percentage Correct
			0	1	
Step 1	Aspiration	0	150	52	74.3
		1	63	56	47.1
	Overall Percentage				64.2
Step 2	Aspiration	0	185	17	91.6
		1	86	33	27.7
	Overall Percentage				67.9
Step 3	Aspiration	0	187	15	92.6
		1	86	33	27.7
	Overall Percentage				68.5

a. The cut value is .500

Variables in the Equation[d]

		B	S.E.	Wald	df	Sig.	Exp{B)
Step 1[a]	Congestion after Eating	.942	.244	14.869		.000	2.564
	Constant	-.868	.150	33.388		.000	.420
Step 2[b]	Congestion after Eating	.925	.249	13.811		.000	2.521
	LRTI Reported	.602	.242	11.001		.001	2.229
	Constant	-1.218	.191	40.694		.000	.296
Step 3[c]	Congestion after Eating	.948	.253	14.099		.000	2.581
	LRTI Reported	.851	.245	12.059		.001	2.341
	Structural Digestive Tract	-20.934	12863.959	.000		.999	.000
	Constant	-1.196	.193	38.615		.000	.302

a. Variable(s) entered on step 1: Congestion after Eating.

b. Variable(s) entered on step 2: LRTI Reported.

c. Variable(s) entered on step 3: Structural Digestive Tract.

d. Stepwise procedure stopped because removing the least significant variable result in a previously fitted model,

Variables not in the Equation

			Score	df	Sig.
Step 1	Variables	Cough with Feed	6.307	1	.012
		Respiratory	9.012	1	.003
		LRTI Reported	11.194	1	.001
		Treaty Number	8.548	1	.003
		Current Diet			
		Oral/Oral and tube/Tube	5.059	1	.024
		Developmental Delay	3.495	1	.062
		Structural Digestive Tract	5.709	1	.017
	Overall Statistics		33.375	7	.000
Step 2	Variables	Cough with Feed	4.899	1	.027
		Respiratory	.079	1	.779
		Treaty Number	4.700	1	.030
		Current Diet			
		Oral/Oral and tube/Tube	4.564	1	.033
		Developmental Delay	3.083	1	.079
		Structural Digestive Tract	6.643	1	.010
	Overall Statistics		22.848	6	.001
Step 3	Variables	Cough with Feed	3.935	1	.047
		Respiratory	.047	1	.828
		Treaty Number	5.048	1	.025
		Current Diet			
		Oral/Oral and tube/Tube	4,827	1	.028
		Developmental Delay	2.257	1	.133
	Overall Statistics		16.445	5	.006

Appendix C: Logistic Regression Predictors of LRTI

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	322	99.1
	Missing Cases	3	.9
	Total	325	100.0
Unselected Cases		0	.0
Total		325	100.0

a. if weight is in effect, see classification table for the total number of cases.

Dependent Variable Encoding

Original Value	Internal Value
0	0
1	1

Block 0: Beginning Block

Classification Table [a,b]

Observed			Predicted		
			LRTI Reported		Percentage Correct
			0	1	
Step 0	LRTI Reported	0	187	0	100.0
		1	135	0	.0
	Overall Percentage				58.1

a. Constant is included in the model.

b. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 0	Constant	-.326	.113	8.324	1	-.004	.722

Variables not in the Equation

			Score	df	Sig.
Step 0	Variables	Aspiration	12.497	1	.000
		Gender	4.537	1	.033
		Respiratory	234.320	1	.000
		Treatynumber	21.565	1	.000
		Neuromuscular	4.320	1	.038
	Overall Statistics		238.077	5	.000

Block 1: Method = Forward Stepwise (Wald)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	291.146	1	.000
	Block	291.146	1	.000
	Model	291.146	1	.000
Step 2	Step	8.733	1	.003
	Block	299.879	2	.000
	Model	299.879	2	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	146.806[a]	.585	.801
2	138.073[a]	.606	.815

Classification Table[a]

Observed			Predicted		
			LRTI Reported		Percentage Correct
			0	1	
Step 1	LRTI Reported	0	163	24	87.2
		1	1	134	99.3
	Overall Percentage				92.2
Step 2	LRTI Reported	0	163	24	87.2
		1	1	134	99.3
	Overall Percentage				92.2

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sfg.	Exp(B)
Step 1[a]	Respiratory	6.814	1.027	43.993	1	.000	910.083
	Constant	-5.094	1.003	25.788	1	.000	.006
Step 2[b]	Respiratory	6.930	1.048	43.747	1	.000	1023.003
	Treaty Number	1.425	.528	7.275	1	.007	4.160
	Constant	-5.683	1.051	29.233	1	.000	.003

a. Vartable(s) entered on step 1: Respiratory.

b. Variable(s) entered on step 2: Treaty Number.

Variables not in the Equation

			Score	df	Slg.
Step 1	Variables	Aspiration	2.537	1	.111
		Gender	.153	1	.695
		Treaty Number	8.157	1	.004
		Neuromuscular	6.000	1	.014
	Overall Statistics		14.756	4	.005
Step 2	Variables	Aspiration	1.653	1	.196
		Gender	.351	1	.554
		Neuromuscular	3.483	1	.062
	Overall Statistics		5.667	3	.129

Appendix D: Logistic Regression Predictors of Indigenous Heritage

Case Processing Summary

Unweighted Cases[8]		N	Percent
Selected Cases	Included in Analysis	321	98.8
	Missing Cases	4	1.2
	Total	325	100.0
Unselected Cases		0	.0
Total		325	100.0

a. if weight is in effect, see classification table for the total number of cases.

Dependent Variable Encoding

Original Value	Internal Value
0	0
1	1

Block 0: Beginning Block

Classification Table[a,b]

		Predicted		
		Treaty Number		Percentage Correct
		0	1	
Step 0				
Treaty Number	0	208	0	100.0
	1	113	0	.0
Overall Percentage				64.8

a. Constant is included in the model.

b. The cut value is .500

Variables in the Equation

	B	S.E.	Wald	df	Sig.	Exp(B)
Step 0 Constant	-.610	.117	27.259	1	.000	.543

Variables not in the Equation

			Score	df	Slg.
Step 0	Variables	Aspiration	10.060	1	.002
		Respiratory	13.527	1	.000
		LRTI Reported	21.260	1	.000
		Current Diet Oral/ Oral and tube/Tube	4.432	1	.035
		Developmental Delay	5.160	4	.023
		Fetal Alcohol Syndrome/Effects	10.030	1	.002
	Overall Statistics		44.598	6	.000

Block 1: Method = Forward Stepwise (Wald)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step Block	21.235	1 1	.000
	Model	21.235	1	. .000
		21.235		.000
Step 2	Step	13.655	1 2	.000
	Block	34.889	2	.000
	Model	34.889		.000
Step 3	Step Block	6.890	1 3	.009
	Model	41.779	3	.000
		41.779		.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	395.225"	.064	.088
2	381.571[3]	.103	.142
3	374.681[8]	.122	.168

a. Estimation terminated at iteration number 4 because parameter estimates changed by less than .001.

Classification Table[a]

Observed		Predicted		
		Treaty Number and/or residence in a First Nations community (n=0.y=1)		Percentage Correct
		0	1	
Step 1	Treaty Number and/or residence in a First Nations community 0	208	0	100.0
	1	113	0	.0
	Overall Percentage			64.8
Step 2	Treaty Number and/or residence in a First Nations community 0	204	4	98.1
	1	102	11	9.7
	Overall Percentage			67.0
Step 3	Treaty Number and/or residence in a First Nations community 0	175	33	84.1
	1 (n=0.y=1)	66	47	41.6
	Overall Percentage			69.2

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step1[a]	LRTI Reported	1.098	.242	20.611		.000	2.999
	Constant	-1.113	.170	42.891		.000	.329
Step 2[b]	LRTI Reported	1.236	.251	24.211		.000	3.442
	F etal Alcohol Syndrome Fetal Alcohol Effects	2.110	.615	11.753		.001	8.247
	Constant	-1.287	.183	49.284		.000	.276
Step 3[c]	Aspiration	.674	.257	6.892		.009	1.961
	LRTI Reported	1.132	.256	19.605		.000	3.102
	Fetal Alcohol Syndrome Fetal Alcohol Effects	2.215	.619	12.819		.000	9.164
	Constant	-1.513	.208	52.704		.000	.220

a. Variable(s) entered on step 1: LRTI Reported.

b. Variable(s) entered on step 2: Fetal Alcohol Syndrome/Fetal Alcohol Effects.

c Variable(s) entered on step 3: Aspiration.

Variables not in the Equation

			Score	df	Sig.
Step 1	Variables	Aspiration	5.662	1	.017
		Respiratory	.355	1	.551
		Current Diet Oral/ Oral and tube/Tube	3.860	1	.049
		Developmental Delay	4.485	1	.034
		Fetal Alcohol Syndrome Fetal Alcohol Effects	15.167	1	.000
	Overall Statistics		25.925	5	.000
Step 2	Variables	Aspiration	6.981	1	.008
		Respiratory	.066	1	.797
		Current Diet Oral/Oral and tube/Tube	4.119	1	.042
		Developmental Delay	2.437	1	.118
	Overall Statistics		10.995	4	.027
Step 3	Variables	Respiratory	.083	1	.773
		Current Diet Oral/Oral and tube/Tube	2.987	1	.084
		Developmental Delay	1.459	1	.227
	Overall Statistics		4.100	3	.251