



Laryngeal penetration on videofluoroscopic swallowing study is associated with increased pneumonia in children[☆]



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ABSTRACT

Objectives: To determine whether children with laryngeal penetration on videofluoroscopic swallowing study are at higher risk for pneumonia than those with normal findings.

Methods: We reviewed the charts of 235 pediatric patients presenting to our Swallowing and Dysphagia clinic for videofluoroscopic swallowing study over a 3-year period. Patients with unsuccessful swallowing studies, incomplete charts, extra-laryngeal etiologies for recurrent pneumonia, or who were lost to follow up were excluded. Out of the 165 patients remaining, 58 had normal findings, 59 had laryngeal penetration, and 48 had tracheobronchial aspiration. The number of cases of pneumonia, aspiration events, and demographic data were recorded for all patients.

Results: Children with laryngeal penetration on videofluoroscopic swallowing study had significantly ($P = 0.032$) more pneumonia than patients with neither penetration nor aspiration (median 2 vs. 0; mean 2.22 vs. 1.60). Furthermore, analysis revealed that glottic abnormalities (e.g. laryngeal cleft) represented a significant independent risk factor ($P = 0.004$) for pneumonia and aspiration, while being diagnosed with a syndrome did not ($P = 0.343$).

Conclusion: To our knowledge, this is the first study to demonstrate that laryngeal penetration on videofluoroscopic swallowing study is associated with significantly more cases of pneumonia in children. While this remains a retrospective study demonstrating a weak association, the results suggest a need for future prospective studies to evaluate this important clinical question in children.

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1. Introduction

It has been estimated that each year in the developed world, there are 2.6 million cases of pediatric pneumonia, resulting in 1.5 million hospitalizations and accounting for 3000 deaths at less than 5 years of age [1]. While the most common cause of community-acquired pneumonia remains viral and bacterial infections, oropharyngeal incoordination with aspiration has been cited as the primary etiology of recurrent pneumonia in childhood [2], accounting for an estimated 8% of pediatric pneumonia hospitalizations [3]. Aspiration is an important etiology of

pneumonia in certain groups of patients, such as children with neurological abnormalities or syndromes [2,4–6]. The swallowing mechanism is complex and difficulty can be encountered at the preparatory, oral, pharyngeal, and esophageal phases [7]. The gold standard diagnostic test for prandial aspiration is a videofluoroscopic swallowing study (VFSS), where a patient ingests barium boluses of various consistencies under radiographic visualization in order to assess the oral and pharyngeal phases of swallowing [2,4,5]. Entry of bolus material below the true vocal folds, known as tracheobronchial aspiration, during VFSS is a clear risk factor for aspiration pneumonia (see Fig. 1A) [4,8]. Laryngeal penetration on the other hand, which is most commonly defined as the passage of material into the laryngeal vestibule but above the true vocal folds (see Fig. 1B) [7–9], requires further investigation [4,10].

There are different degrees of laryngeal penetration, as best described by Rosenbek and colleagues [9] in the Penetration–Aspiration Scale, and it may occur before, during, or after the pharyngeal phase of swallowing [7]. In 2000, Friedman and colleagues [8] demonstrated that out of 125 children with

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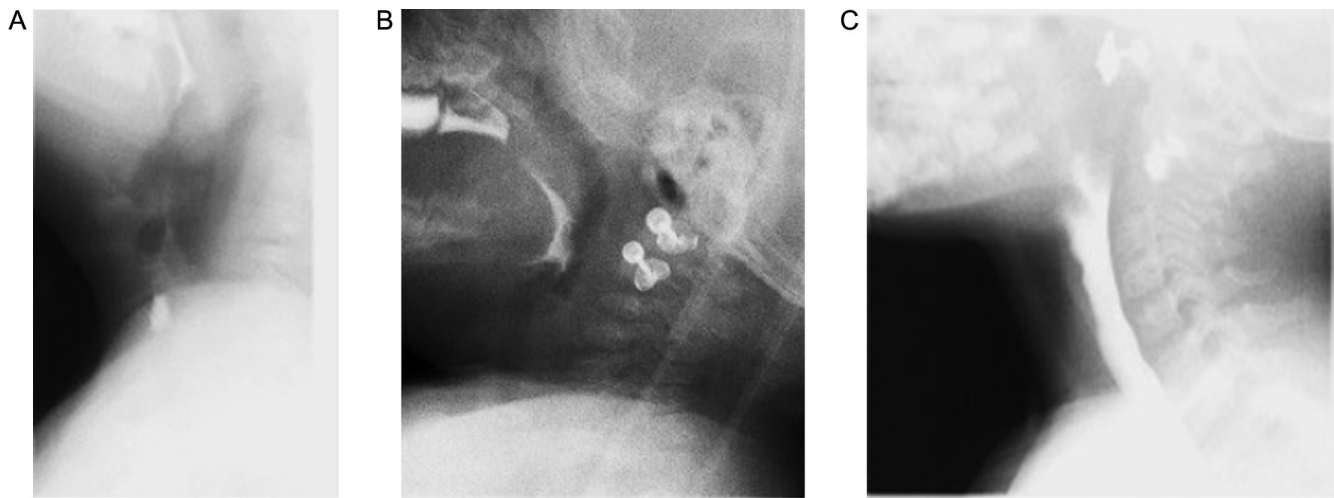


Fig. 1. VFSS outcomes. (A) Tracheobronchial aspiration in a 2-year-old male. (B) Laryngeal penetration in a 6-month-old female. (C) Neither aspiration nor penetration in a 5-year-old female.

dysphagia, 60% exhibited laryngeal penetration including 31% with deep laryngeal penetration (the bolus contacting the vocal cords). Importantly, 85% of these children aspirated later over the course of an extended VFSS, suggesting a strong correlation between laryngeal penetration and tracheobronchial aspiration [8]. However, this study did not look at clinical outcomes. Furthermore, a large study of 381 adults with 6 months of clinical follow up demonstrated that patients with laryngeal penetration were approximately four times ($P=0.008$) more likely to develop pneumonia than those with normal swallowing [4]. Thus, there is evidence that laryngeal penetration on VFSS may represent an early sign of aspiration as well as evidence that laryngeal penetration increases the risk of pneumonia in adults, but presently there is no study evaluating the clinical significance of laryngeal penetration in children. The objective of this study is to determine if laryngeal penetration on VFSS is associated with increased pneumonia in this age group.

2. Materials and methods

2.1. Subjects

The study population consisted of 235 pediatric patients consecutively referred to our Swallowing and Dysphagia clinic for a VFSS from 2008 to 2011. Patients with a prematurely

terminated VFSS, those who were not primarily followed at our hospital center, patients who exhibited extra-laryngeal etiologies of pneumonia, and those who were lost to follow up were excluded. This left 165 patients, representing a wide range of diagnoses (see Fig. 2).

2.2. Data collection

Videofluoroscopic swallowing studies were performed at our center in a standardized fashion in the presence of a radiologist and an occupational therapist. The patient was seated in a tumble form seat, and was given barium admixed with various textures of food under fluoroscopic monitoring. The reports of the occupational therapist and radiologist were reviewed in a retrospective fashion and patients were classified into three cohorts based on their findings: “neither penetration nor aspiration”, “laryngeal penetration”, or “tracheobronchial aspiration”. When different degrees of swallowing dysfunction were seen with different textures, the most dysfunctional finding was recorded for that patient. A patient who exhibited laryngeal penetration but then aspirated later in the same VFSS was classified as an aspirator. If a patient had multiple swallowing studies, the first test was recorded.

After receiving institutional review board approval, each patient’s complete medical history was reviewed in a retrospective fashion for the number of cases of pneumonia, aspiration events, clinical diagnoses, demographic data, syndromes, glottic abnormalities, days hospitalized as a result of pneumonia, and number of antibiotic prescriptions. A case of pneumonia was defined as a clinical diagnosis of pneumonia made by a physician along with consolidation on chest X-ray. Glottic abnormalities were documented via flexible laryngoscopy and rigid bronchoscopy reports. Syndromes were defined as clinically significant and recognized diseases having the word “syndrome” in their name. We also attempted to classify the degree of laryngeal penetration for each patient using the Penetration–Aspiration Scale [9].

2.3. Statistical analysis

Normality was determined using the Shapiro–Wilk test. Analysis of differences in central tendency was undertaken using the Mann–Whitney–*U* non-parametric statistic. A Chi-square test was used for demographic comparisons between cohorts. All analysis was performed using the Statistical Package for the Social Sciences (SPSS; IBM Inc.).

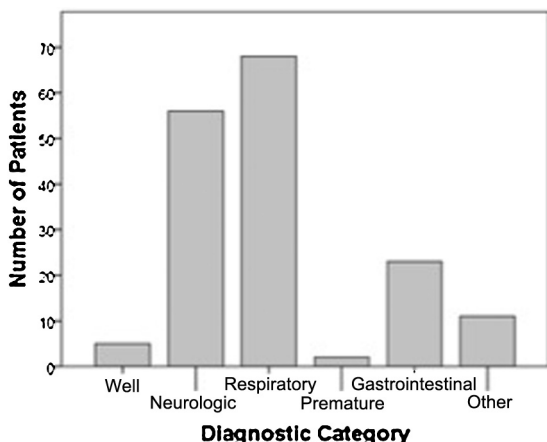


Fig. 2. Diagnostic categories of subjects.

3. Results

3.1. Patient attributes

The primary diagnostic categories of the patients in each cohort can be found in Table 1. Note that the most common diagnoses in all groups were neurologic and respiratory conditions. In fact, 41.2% of our sample of 165 children had a documented neurological illness.

The composition of all groups was similar. Specifically, there was no statistically significant difference between the “neither penetration nor aspiration” and “laryngeal penetration” cohorts in terms of gender ($P = 0.945$), proportion of syndromic patients ($P = 0.771$), or proportion of premature patients ($P = 0.497$) (see Table 2). A multitude of syndromes were encountered, with the most common being trisomy 21. Note that there were significantly more patients with glottic abnormalities in the laryngeal penetration group ($P = 0.005$), with the most common glottic abnormalities being laryngeal cleft and vocal cord paralysis. Importantly, there was no significant difference between mean age at VFSS ($P = 0.07$) and mean follow up time post-VFSS ($P = 0.189$) between our two cohorts of interest, “within normal limits” and “laryngeal penetration”. The same could be said for the “laryngeal penetration” and “tracheo-bronchial aspiration” cohorts ($P = 0.365$ and $P = 0.511$, respectively, see Table 2).

3.2. VFSS findings

Out of 165 patients, 58 had neither laryngeal penetration nor aspiration, 59 had laryngeal penetration, and 48 had tracheobronchial aspiration. Unfortunately, the pharyngeal phases of the studies were not reported in enough detail to accurately grade performance using the Penetration–Aspiration Scale.

Table 1
Primary diagnostic categories of subjects in each cohort.

	All	∅Pen/Asp ^a	Laryngeal penetration	Aspiration
Well	5 (3%)	2 (3.4%)	2 (3.4%)	1 (2.1%)
Neurologic	56 (33.9%)	19 (32.8%)	14 (23.7%)	23 (47.9%)
Respiratory	68 (41.2%)	25 (43.1%)	25 (42.4%)	18 (37.5%)
Gastrointestinal	23 (13.9%)	7 (12.1%)	13 (22%)	3 (6.3%)
Other	11 (6.7%)	5 (8.6%)	4 (6.8%)	2 (4.2%)
Total	165 (100%)	58 (100%)	59 (100%)	48(100%)

^a Neither penetration nor aspiration.

Table 2
Patient attributes in each cohort.

	∅Pen/Asp ^a	Penetration	Aspiration
Male	37 (63.8%)	38 (64.4%)	21 (43.8%)
Female	21 (36.2%)	21 (35.6%)	27 (56.3%)
Premature	9 (15.5%)	12 (20.3%)	6 (12.5%)
Term	49 (84.5%)	47 (79.7%)	42 (87.5%)
Syndrome	10 (17.2%)	9 (15.3%)	11 (22.9%)
No syndrome	48 (82.8%)	50 (84.7%)	37 (77.1%)
Upper airway anomaly ^b	4/34 (6.9%)	17/42 (28.8%)	11/35 (22.9%)
Normal upper airway ^b	30/34 (51.7%)	25/42 (42.4%)	24/35 (50%)
Mean age at VMBS (months)	67.21 (0–210)	44.02 (1–204)	36.89 (1–240)
Mean follow-up post-VMBS (months)	50.69 (14–175)	39.98 (12–151)	44.67 (10–164)

^a Neither penetration nor aspiration.

^b Upper airway anomaly data represents a sub-analysis of 111 patients who underwent flexible laryngoscopy or rigid bronchoscopy.

3.3. Pneumonia and aspiration

3.3.1. Effect of VFSS result

Analysis showed that children with laryngeal penetration had significantly ($P = 0.032$) more cases of pneumonia and aspiration than patients with neither penetration nor aspiration on VFSS (median 2 vs. 0) (see Fig. 3A). There was no significant difference

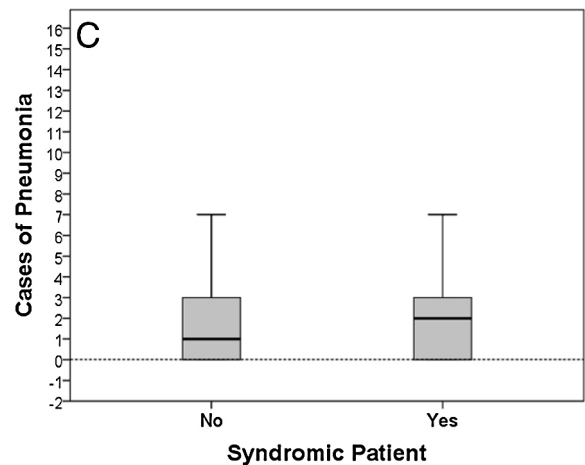
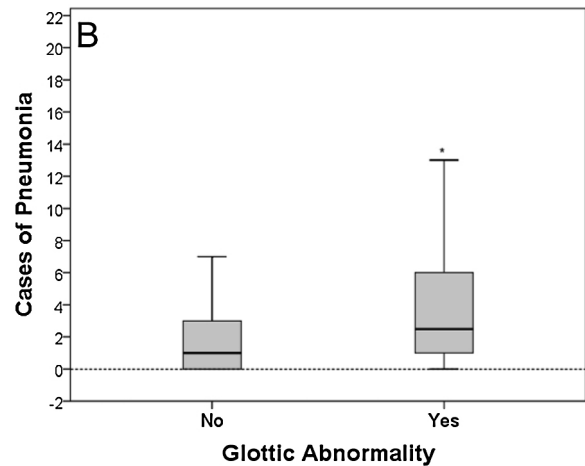
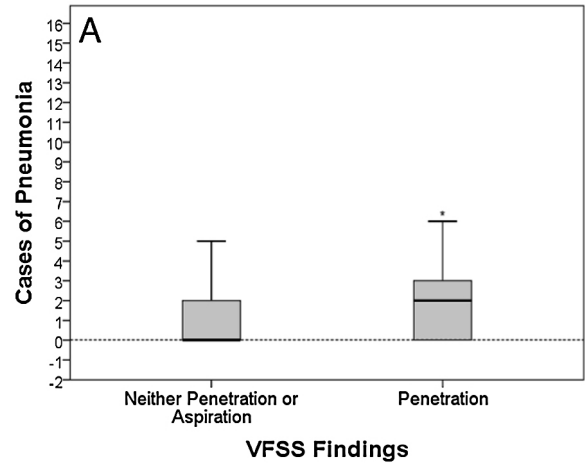


Fig. 3. Median number of pneumonias. (A) Median number of pneumonias vs. VFSS findings. (B) Median number of pneumonias vs. glottic abnormality. (C) Median number of pneumonias vs. syndromic patient. * Significant.

between the “neither penetration nor aspiration” and laryngeal penetration cohorts when evaluated within each given texture category ($P=0.097$ for thin liquid, $P=0.113$ for thick liquid, $P=0.835$ for puree, $P=0.748$ for solid).

3.3.2. Effect of glottic abnormalities

A sub-analysis of 111 children with documented laryngoscopies or bronchoscopies revealed that those with glottic abnormalities had significantly more ($P=0.004$) cases of pneumonia than children with normal anatomy (median 2.5 vs. 1) (Fig. 3B).

3.4. Effect of syndromes

Having been diagnosed with a syndrome was not associated with significantly more ($P=0.343$) cases of pneumonia (Fig. 3C).

3.5. Days hospitalized and number of antibiotic prescriptions

There was no significant difference between the number of days hospitalized ($P=0.180$) or the number of antibiotic prescriptions ($P=0.079$) between the laryngeal penetration and the neither penetration nor aspiration cohorts.

4. Discussion

To our knowledge, this study is the first to demonstrate that laryngeal penetration on VFSS is associated with significantly more cases of pneumonia in children. This was demonstrated in a large sample of children with long-term follow up. Importantly, the cohorts of interest had similar demographics, age at VFSS, and duration of follow up.

Limitations of this study include its retrospective nature and the fact that several of our sub-analyses may have been limited by a small sample size. Furthermore, while differences in practice between various physicians may explain the lack of significant difference in days hospitalized between children with laryngeal penetration and those with neither penetration nor aspiration, it is more difficult to explain the lack of difference in antibiotic prescriptions. Also, as with other retrospective studies of pneumonia [4], it was difficult to ascertain whether a given case was actually caused by aspiration, thus other etiologies of pneumonia may have been unintentionally included such as bacterial and viral pneumonia. There is also the potential confounder of the laryngeal penetration cohort comprising significantly more patients with glottic abnormalities, which we demonstrate in this study to be an independent risk factor for pneumonia in itself.

Despite these limitations, this is the first study to evaluate the clinical implications of laryngeal penetration in children, an under-investigated and important clinical question. We have demonstrated that, similar to adults [4], laryngeal penetration on VFSS in children is associated with significantly more cases pneumonia. More specifically, the median number of pneumonias in laryngeal penetrators over the follow-up period was 2, compared to 0 in subjects with normal findings on VFSS. While the clinical

significance of two more cases of pneumonia may be questionable in well children, a single pneumonia in an unwell child or one with a neurological disease may have dire complications including hospitalization, ICU admission, or even death [11].

Future work is required to ascertain whether our findings can be reproduced in a prospective study. Furthermore, it would be informative to evaluate whether increasing degrees of laryngeal penetration (according to the Scale by Rosenbek and colleagues for example [9]) are associated with higher risks of pneumonia. Finally, one could ask whether modifying food textures that produced laryngeal penetration on VFSS could reduce the number of cases of pneumonia in children.

5. Conclusion

With the current ambiguity of laryngeal penetration on VFSS in children, the high incidence of this finding on videofluoroscopic swallowing studies [8], and the serious complications of repeated aspiration, which include recurrent pneumonia, chronic lung disease, and failure to thrive, further research is needed to help guide medical teams in the management of children with laryngeal penetration [7].

Conflict of interest

The authors have no conflict of interest to disclose.

Financial disclosures

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