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Laryngeal sensation and its association with aspiration and cough in children with neurological impairment

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Abstract

Background: Aspirations are frequent in children with neurological impairment. They significantly increase the risk for acute and chronic respiratory insufficiencies leading to high morbidity and mortality. Laryngeal sensation deficits have been linked to aspirations in adults and are a suspected cause for dysphagia in children. In a similar neurological circuit as swallowing, laryngeal receptors trigger coughing as a protective airway reflex. The aim of this study was to examine the association between impaired laryngeal sensation (ILS), aspiration, and coughing in neurologically impaired children.

Design and Methods: In a retrospective study, 110 children with suspected dysphagia underwent a clinical evaluation of swallowing and a flexible endoscopic evaluation of swallowing (FEES) between 2013 and 2019 in the children's university clinic Düsseldorf were analyzed. Laryngeal sensation was tested by the endoscopic touch method. Associations were computed using χ^2-test.

Results: Fifty-four patients (49.1%) had a neurological impairment, 56 patients (50.9%) had no or other comorbidities and served as a control cohort. Children with neurological impairment suffered from ILS significantly more often than children with no or other comorbidities ($\chi^2(1) = 4.63$, $p = .031$). ILS was associated with all other FEES variables but did not correlate with coughing. The symptom coughing correlated with aspiration in the group of neurologically impaired children and in children ILS.

Conclusion: ILS is a potential cause of aspirations in children with neurological impairment. Physicians need to pay special attention to the occurrence of coughing in children with neurological impairment and/or ILS since it signals aspirations that took place.

KEYWORDS

FEES, pediatric dysphagia, sensory deficit, sensibility, sensitivity, dysphagia, ILS

1 | INTRODUCTION

Children with severe neurological impairment are at higher risk for aspiration.[1] The most common cause is swallowing disorders, followed by gastroesophageal reflux and insufficient management of nasal/oral secretions.[2] The growing incidence of pediatric dysphagia is, among other things, due to advances in prenatal and pediatric care which lead to an increased survival rate of premature infants and children with complex neurological diseases.[3]

Aspirations are common in children with neurological impairment; 99% of children with severe generalized cerebral palsy and intellectual disability are affected.[4] Chronic aspirations endanger the children's health in the short and long term. Direct aspirations are a major cause of pulmonary infections in children with neurological impairment.[5] Additionally, these children are more frequently affected by chronic pulmonary infections, protracted bacterial bronchitis, and bronchiectasis.[6] Ultimately, respiratory insufficiency is the leading cause of hospital admission and death in children with neurological impairment.[7,8]

It is still not fully understood why children with neurological impairment are at an increased risk for aspirations and why they often remain unnoticed (silent aspirations).[1] In healthy patients, stimulation of the mechanoreceptors that are distributed all over the pharynx and larynx results in swallowing.[9] Therefore, an increased reception threshold might lead to an impaired swallowing function. Ramsey et al. have linked aspiration to an impaired laryngeal sensation (ILS) and/or the inability to cough in a systematic review considering mostly adult studies.[10] It has already been demonstrated that ILS was directly associated with the severity of (poststroke) dysphagia in adults.[11] Additionally, Aviv et al. showed that pneumonia develops more often in adult patients when laryngeal sensation is reduced.[12] Data on the pediatric population is still very rare; it needs further investigations whether findings in adults also apply to children.

Coughing is a secondary airway defense mechanism. It comes into place when larger amounts of aspirated materials cannot be eliminated by mucociliary clearance, alveolar macrophages, or neutrophils. If aspirated materials are not eliminated immediately from the airway, they will cause pulmonary diseases.[13] Thus an adequate cough reflex is necessary to protect against acute and chronic respiratory problems. Similar to the process of swallowing, coughing is triggered by mechanoreceptors and chemoreceptors in the larynx and the trachea. Numbing of the larynx by topical application of lidocaine will suppress the cough reflex effectively as one can observe in pediatric bronchoscopy.[14,15] ILS might therefore result in an ineffective or absent cough.

It is well conceivable from clinical practice that ILS in children with neurological disorders results in a failure to recognize food, saliva, or gastroesophageal reflux and hence leads to impaired swallowing and aspiration. We hypothesize that in children with neurological impairment, ILS leads to a higher threshold for cough and therefore to aspirations. The aim of this study was to identify whether children with neurological impairment have ILS, cough less and aspirate more in comparison to children with no or other comorbidities.

2 | MATERIAL AND METHODS

2.1 | Study design and population

The charts of children between 0 and 18 years of age who presented with suspected swallowing disorders between 2013 and 2019 at the Children's Hospital of the University clinic Düsseldorf, Germany, were reviewed retrospectively. The inclusion criteria were the completion of both clinical swallowing evaluation (CSE) as well as a fiberoptic evaluation of swallowing (FEES) in the respective time interval. Children suffering from fever or any other signs of acute infection were excluded from swallowing diagnostics and therefore not included in this study. The children were either inpatients or outpatients referred by their physicians. Assignment to a specialty was made in consultation with the research team based on the primary diagnosis. Children with a primary diagnosis in the field of neuropediatrics will further be referred to as neurologically impaired children.

In the medical records, the presence or absence of aspiration was documented. We summarized some of the symptoms assessed in CSE as respiratory symptoms including coughing, above-average number of respiratory tract infections, wet voice/wet breathing, stridor, and fever. Those were either reported by the caregivers or observed during CSE. Coughing was marked as present when either the caregivers reported its occurrence independently of respiratory infections or when it was in temporal context of drinking and/or eating during CSE.

The study was approved by the local ethical committee of the Heinrich-Heine University Düsseldorf, Germany (Registration ID 2015094347, study number 5253R).

2.2 | Swallowing examination

CSE was performed before FEES by our speech and language pathologist. The protocol for CSE consists of a comprehensive case history, a check of the swallowing-relevant motor and sensory functions, and of a direct test with food, allowing it to be close to everyday food intake.[16,17] Clinical symptoms serve as decision factors for or against the presence of a swallowing disorder or aspiration.[18]

FEES was performed by our senior physician in pediatric pulmonology using endoscopes with an outer diameter of 2.1 or 2.8 mm according to the child's size. It included the assessment of the structural and functional anatomy of the hypopharynx and larynx. Anatomical abnormalities such as suspected laryngeal cleft, laryngomalacia, or vocal cord paresis were documented. Furthermore, drinking and eating of different textures according to the patients' age were observed and the following parameters were recorded: premature spillage, laryngeal penetration, aspiration, and residue of the bolus in the hypopharynx after swallowing. For the evaluation of

laryngopharyngeal sensation, the aryepiglottic fold was touched with the tip of the endoscope.[19] If no immediate swallowing, cough, or laryngeal adductor reflex was observed, ILS was assumed.

After CSE and FEES, recommendations regarding the change of diet or oro-facial therapy were made in consultation with both specialists.

We do not perform CSE or FEES when the patient suffers from fever or any other signs of an acute infection.

2.3 | Statistical analysis

Statistical analysis was carried out using SPSS Statistics 27 (IBM, USA). Patients with neurological impairment were compared to those without. Descriptive analysis was conducted for the sample profile of both groups, encompassing age, presence or absence of respiratory symptoms, anatomical abnormalities found during FEES, and laryngopharyngeal sensation. Values are presented as mean ± standard deviation, median, range, or percentage. χ^2 tests for association were performed between presence of respiratory symptoms and results of the FEES. χ^2 tests were also used to compare respiratory symptoms, outcomes of the FEES and laryngopharyngeal sensation between patients with neurological impairment and the control cohort. All analyses were conducted at an α-level .05 significance.

3 | RESULTS

A total of 132 CSE and FEES examinations were performed on 110 children with suspected dysphagia. The initial CSE and FEES done for each patient were used for the analysis. CSE and FEES were performed on an outpatient basis in 71 (64.5%) patients. Out of the remaining 39 (35.5%) patients, 33 were hospitalized for advanced swallowing diagnostics, 2 for surgical insertion/switch of percutaneous feeding tube, and 4 for other comorbidities.

The mean (SD) age of the patients was 3.4 (±3.8) years. Overall, patients showed a mean (SD) number of 1.8 (±1.1) respiratory symptoms, with coughing being the most frequent one (56.4%), followed by wet breathing (50.0%) and lower respiratory tract infections (45.5%).

Fifty-four (49.1%) patients had neurological impairment; the remaining 46 (50.9%) children had no or other comorbidities in the field of a different specialty and served as the control cohort. The age of the patients, the number of respiratory symptoms, and the composition of the control cohort can be found in Table 1.

In the group of children with neurological impairment, 28 (51.9%) suffered from genetic syndromes, 12 (22.2%) had cerebral palsy, 7 (12.9%) had documented encephalopathy, 2 (3.7%) had structural brain defects and in 5 (9.3%) patients no clear diagnosis could be extracted from the charts.

In the control cohort, past prematurity (18.2%) was the predominant underlying pathology; these children were allocated to Neonatology. Mean gestational age (SD) was 29.1 (±3.6) weeks; however, all swallowing examinations were carried out past neonatal age.

Five children (4.5%) were allocated to gastroenterology of whom two suffered from gastroesophageal reflux disease. A comparison between children with and without neurological impairment in regard to their respiratory symptoms is displayed in Table 2.

Across all children, 98 (89.1%) showed at least one abnormal finding of the swallowing process during FEES. Residue of the bolus in the hypopharynx after swallowing was the most frequent finding (64.6%). Aspiration occurred in 40.9% of cases. More than half of the patients showed a laryngopharyngeal sensory deficit (54.6%). Table 3

TABLE 1 Sample profile

			Age in years				No. respiratory symptoms	
	n = 110	%	Mean	± SD	*p* value	Range	Median	Range
Children with neurological impairment	54	49.1	4.3	±4.3	>0.05	0.1–17.1	1.0	0–4
Children with no or other comorbidities[a]	56	50.9	2.6	±3.2		0.1–16.3	2.0	0–4
Neonatology	20	18.2						
Pulmonology	4	3.6						
Cardiology	7	6.4						
Metabolic disorder	5	4.5						
Gastroenterology	5	4.5						
No comorbidities	3	2.7						
Rheumatology/oncology/immunology	2	1.8						

[a]Other comorbidities are further subcategorized according to the specialty supervising the main diagnosis.

TABLE 2 Respiratory symptoms as obtained during CSE $n = 110$

	Children with neurological impairment		Children with no or other comorbidities	
	$n = 54$	%	$n = 56$	%
Coughing	26	48.1	36	64.3
Wet breathing	24	44.4	31	55.4
Lower respiratory infections	18	33.3	32	57.1
Stridor	12	22.2	16	28.6
Fever	5	9.3	2	3.6

Note: Coughing was assumed when it occurred either in noninfectious periods or in the context of meals

Abbreviations: CSE, clinical swallowing evaluation; n, sample size.

TABLE 3 FEES pathologies

	Children with neurological impairment		Children with no or other comorbidities			
	$n = 54$	%	$n = 56$	%	$\chi^2(1)$	p value[a]
Premature spillage	38	70.4	29	51.8	3.581	.058
Residues	38	70.4	33	58.9	1.573	.210
Aspiration	25	46.3	20	35.7	1.273	.259
Penetration	33	61.1	27	48.2	1.844	.174
Anatomical abnormalities	15	27.8	16	28.6	.045	.832

Abbreviations: FEES, fiberoptic endoscopic evaluation of swallowing; n, sample size; $\chi^2(1)$, value of the test statistics.

[a]Fisher's exact test.

gives an overview of the FEES pathologies divided by the presence or absence of neurological impairment. The overall correlation between CSE and FEES results was strong; only six patients (0.05%) showed differing results in the two examinations.

There was a significant correlation between neurological impairment and ILS ($\chi^2(1) = 4.63$, $p = .031$, $\varphi = 0.207$), meaning that children with neurological impairment suffered from ILS significantly more often than children with no or other underlying pathologies. ILS was directly associated with premature spillage ($\chi^2(1) = 32.42$, $p < .001$, $\varphi = 0.548$), penetration ($\chi^2(1) = 19.05$, $p < .001$, $\varphi = 0.420$), aspiration ($\chi^2(1) = 14.18$, $p < .001$, $\varphi = 0.362$) and residues ($\chi^2(1) = 22.12$, $p < .001$, $\varphi = 0.453$).

Coughing was present in 26 out of 54 patients (48.1%) with neurological impairment, while 36 out of 56 children (64.3%) with no or other comorbidities presented with coughing ($\chi^2(1) = 2.911$, $p = .088$, $\varphi = -0.163$). ILS did not correlate with coughing, meaning that children with ILS did not present coughing significantly less often than children with regular laryngeal sensation ($\chi^2(1) = 0.121$, $p = .728$, $\varphi = -0.33$).

Table 4 gives an overview of the presence of coughing and aspiration as well as the probability of both pathologies occurring in one patient. It is evident that coughing and aspiration correlate significantly in the group of children with neurological impairment. Children with ILS also showed a significant correlation between coughing and aspiration while this was not the case in children without ILS.

4 | DISCUSSION

The primary aim of this study was to assess whether ILS in children with neurological impairment is associated with a higher incidence of aspiration and whether coughing can predict aspiration in children with ILS. We have been able to show that an underlying neurological disease is a risk factor for ILS in children, which is in line with previous studies.[20,21] We could also demonstrate that ILS is associated with premature spillage, penetration, aspiration, and residue which is consistent with previous study results.[20,22]

To date, no reliable clinical markers for swallowing disorders in children are known.[23] In our study, coughing was associated with aspiration in the group of children with neurological impairment and in children with ILS. In healthy children or children with other comorbidities, coughing was not associated with aspiration. It seems that there is a higher threshold for coughing in children with neurological impairment and/or ILS. If coughing is observed in these children, it functions as a warning signal for an aspiration that just took place.

Coughing is a protective airway reflex that is initiated by a complex network of pathways. Recent research suggests a dual-sensory neuron model: Coughing is induced either by chemically stimulated C-fibers or by mechanically stimulated sensory fibers.[24] The latter is often referred to as cough receptors and they answer particularly well to punctual stimulation of the mucosa.[24]

Based on this neurophysiological foundation, we expected children with a decreased or absent reaction to the endoscopic touch of the laryngeal mucosa to cough less frequently than children with a regular laryngeal sensation do. Yet, the presence of coughing was as frequently observed in children with or without ILS. This contradiction raises the question of whether laryngeal sensation was reliably tested with the applied touch method. The tip of the endoscope is used to touch the arytenoids or the epiglottis bilaterally which is the region with the highest density of sensory receptors in the larynx.[25] Following the stimulation, the presence or absence of a defense reaction such as an immediate swallow, cough, gagging, or the laryngeal adductor reflex (LAR) is observed.

Despite the high prevalence of LAR measurement by endoscopic touch, its inter-rater reliability is insufficient.[19] An alternative method to test the LAR is by an air-pulse applied through the working channel of the endoscope, a technique first described by Aviv et al. in 1993.[26] It offers graduations in the intensity of the air pulse ranging from <4 mmHg (normal sensory threshold) over 4–6 mmHg (moderately

TABLE 4 Correlation between abnormal or above-average coughing and aspirations as observed during FEES

		Coughing		Aspiration		Both coughing and aspiration		
	n = 110	*n*	%	*n*	%	*n*	$\chi^2(1)$	*p* value[a]
ILS	60	33	55.0	34	56.7	23	**5.071**	**.024**
No ILS	48	28	58.3	10	20.8	7	.707	.400
Children with neurological impairment	54	26	48.1	25	46.3	16	**4.685**	**.030**
ILS	35[b]	17	48.6	22	62.9	15	**9.119**	**.003**
No ILS	18	9	50.0	3	16.7	1	.400	.527
Children with no or other comorbidities	56	36	64.3	20	35.7	15	1.556	.212
ILS	25[c]	16	64.0	12	48.0	8	.071	.790
No ILS	30	19	63.3	7	23.3	6	1.969	.161

Abbreviations: FEES, fiberoptic endoscopic evaluation of swallowing; *n*, sample size; $\chi^2(1)$, value of the test statistics; ILS, impaired laryngeal sensation.

[a]Fisher's exact test.

[b]One value for ILS is missing in the group of children with neurological impairment.

[c]One value for ILS is missing in the group of children with no or other comorbidities.

impaired sensation) to >6 mmHg (severely impaired sensation). The downsides of the air pulse technique encompass the loudness of the device (which produces a bias due to an additional auditory signal), its limited availability, and the need for an additional device during FEES.[21] Both methods of testing the LAR—the endoscopic touch and the air pulse technique—have been shown to inadequately predict responsiveness to residue, penetration, and or aspiration.[27] Kaneoka et al. found that the air pulse technique identifies sensory deficits more frequently than the touch method, but that only sensory deficits found in the touch method were associated with penetration and or aspiration.[28]

In our cohort, ILS—identified by the touch method—was not associated with a lower frequency of coughing. Assuming that the touch method identifies only severe sensory deficits, we hypothesize that the coughing reflex is already affected by slightly or moderately reduced sensibility. The lack of discrimination between minimal, moderate, and severe sensory deficits would hence explain why our measurement did not correlate with coughing. We however observed a trend that children with neurological impairment cough less frequently than children with no or other comorbidities. This might be due to greater laryngeal sensory deficits in children with neurological impairment compared to those with no or other comorbidities.[29]

There are several limitations to this study; most of them result from its retrospective design. Firstly, an aspiration during FEES is not differentiated according to timing (pre- vs. postdeglutitive) nor did we properly document silent aspirations. It would be an interesting avenue for future studies to investigate the association between ILS and silent aspiration; especially in neurologically impaired children. Furthermore, there is heterogeneity in the group of neurologically impaired children since they suffered from different underlying diseases with different levels of severity. We cannot completely rule out that children of the control cohort might suffer from some degree of neurological impairment. In prospective designs, severity levels of neurological impairment should be differentiated (e.g., Gross Motor Function Classification System).

For a more detailed evaluation of the association between cough reflex, laryngeal sensation, and aspiration, we propose a critical questioning of the currently widespread techniques for laryngeal sensory measurement. Furthermore, we believe that additional parameters such as the occurrence of silent aspiration, the time interval between laryngeal stimulation and defense reaction, the frequency of coughing, and the volume as well as the texture of trialed food should be documented in detail during FEES.

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AUTHOR CONTRIBUTIONS

Nadine Freitag helped with conceptualization (lead); methodology (equal); writing original draft (lead). Pia Tews: formal analysis (lead); visualization (supporting); writing original draft (supporting). Nicole Hübl helped with investigation (equal); resources (equal); writing review & editing (supporting). Katrin Krug helped with conceptualization (supporting); methodology (equal). Julia Kristin: resources (supporting); supervision (supporting). Felix Distelmaier helped with conceptualization (supporting); resources (supporting); supervision (supporting). Dirk Schramm helped with conceptualization (lead); investigation (equal); resources (equal); supervision (lead); writing review & editing (equal).

CONFLICT OF INTERESTS

The authors declare that there are no conflict of interests.

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