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Pediatrics. Author manuscript; available in PMC 2019 January 07.

Published in final edited form as:

Pediatrics. 2016 February ; 137(2): e20151612. doi:10.1542/peds.2015-1612.

Aspiration and Non-Aspiration Pneumonia in Hospitalized Children With Neurologic Impairment

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Abstract

BACKGROUND AND OBJECTIVE: Children with neurologic impairment (NI) are commonly hospitalized for different types of pneumonia, including aspiration pneumonia. We sought to compare hospital management and outcomes of children with NI diagnosed with aspiration versus nonaspiration pneumonia.

METHODS: A retrospective study of 27 455 hospitalized children aged 1 to 18 years with NI diagnosed with pneumonia from 2007 to 2012 at 40 children's hospitals in the Pediatric Health Information System database. The primary exposure was pneumonia type, classified as aspiration or nonaspiration. Outcomes were complications (eg, acute respiratory failure) and hospital utilization (eg, length of stay, 30-day readmission). Multivariable regression was used to assess the

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Dr Thomson conceptualized and designed the study, interpreted the data, and drafted the initial manuscript; Dr Hall aided in study design, conducted the statistical analyses data analysis, supervised interpretation of the data, and reviewed and revised the manuscript; Drs Ambroggio, Stone, and Srivastava aided study design, participated in the interpretation of the data, and reviewed and revised the manuscript; Drs Shah and Berry supervised the conceptualization and design of the study, supervised interpretation of the data, and reviewed and revised the manuscript; and all authors approved the final manuscript as submitted.

POTENTIAL CONFLICT OF INTEREST: The authors have indicated they have no potential conflicts of interest to disclose.

FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

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association between pneumonia type and outcomes, adjusting for NI type, comorbid conditions, and other characteristics.

RESULTS: In multivariable analysis, the 9.7% of children diagnosed with aspiration pneumonia experienced more complications than children with nonaspiration pneumonia (34.0% vs 15.2%, adjusted odds ratio [aOR] 1.2 (95% confidence interval [CI] 1.1–1.3). Children with aspiration pneumonia had significantly longer length of stay (median 5 vs 3 days; ratio of means 1.2; 95% CI 1.2–1.3); more ICU transfers (4.3% vs 1.5%; aOR 1.4; 95% CI 1.1–1.9); greater hospitalization costs (median $11 594 vs $5162; ratio of means 1.2; 95% CI 1.2–1.3); and more 30-day readmissions (17.4% vs 6.8%; aOR 1.3; 95% CI 1.2–1.5).

CONCLUSIONS: Hospitalized children with NI diagnosed with aspiration pneumonia have more complications and use more hospital resources than when diagnosed with nonaspiration pneumonia. Additional investigation is needed to understand the reasons for these differences.

Children with neurologic impairment (NI) account for an increasing and disproportionate amount of inpatient hospital resources.[1] A variety of neurologic diseases are responsible for NI (eg, hypoxic-ischemic encephalopathy, lissencephaly). NI can lead to respiratory insufficiency from central hypoventilation, gastroesophageal reflux, impaired cough, oromotor dysfunction and dysphagia, and respiratory muscle weakness.[2,3] This insufficiency predisposes children with NI to respiratory infection from exogenous sources (eg, community acquired viral or bacterial pneumonia) and endogenous sources (eg, aspiration of saliva or gastric contents). In children with NI, pneumonia is one of the most common reasons for hospitalization, admission to an ICU, and death.[1,4–6]

In our clinical experience, pneumonia in children with NI, compared with otherwise healthy children, can be challenging to diagnose and treat because no validated clinical practice guidelines exist for pneumonia in children with NI. Little is known about the evaluation, management, and outcomes of pneumonia in children with NI. Moreover, there is a paucity of information on differences in these attributes between aspiration and nonaspiration pneumonia. In adults, aspiration pneumonia is associated with different treatment approaches (eg, higher use of anaerobic antimicrobial agents), increased hospital resource use, and worse health outcomes than nonaspiration pneumonia.[7–11]

Therefore, the objective of this study was to compare evaluation, management, and outcomes associated with a diagnosis of aspiration versus nonaspiration pneumonia in a multiinstitutional cohort of hospitalized children with NI.

METHODS

Study Design and Data Source

This multicenter, retrospective, cohort study included data from the Pediatric Health Information System (PHIS), an administrative database of 43 not-for-profit, tertiary care, US pediatric hospitals affiliated with Children's Hospital Association (Overland Park, KS). PHIS contains data regarding patient demographics, diagnoses and procedures (with *International Classification of Diseases, Ninth Revision, Clinical Modification* [*ICD-9-CM*] codes), and daily billed resource utilization (eg, laboratory studies, radiologic imaging, and

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pharmaceuticals). Encrypted medical record numbers permit identification of patients across multiple visits to the same hospital. Data quality and reliability are ensured through the Children's Hospital Association and participating hospitals. Three hospitals were excluded because of data quality issues.

Study Population

Inclusion Criteria—Hospitalizations of children 1 to 18 years of age who were discharged between July 1, 2007, and June 30, 2012, were included if they had a NI *ICD-9-CM* diagnosis code[1] and a principal diagnosis of either aspiration pneumonia or nonaspiration pneumonia. NI was defined as functional and/or intellectual impairment that resulted from a neurologic disease using a previously defined set of 606 *ICD9-CM* diagnosis codes.[1] Infants <1 year were excluded because many NI diagnoses (eg, cerebral palsy) are not assigned until an older age. Hospitalizations with a principal diagnosis of pneumonia (aspiration or nonaspiration) were identified with *ICD-9-CM* diagnosis codes based on previously used methods.[7,8,10–13] Principal diagnosis is the condition established as chiefly responsible for hospital admission.[14] Aspiration pneumonia codes were 507.× (eg, "pneumonitis due to solids and liquids").[7,8,10,11,13] Nonaspiration pneumonia codes included those for pneumonia (480.0–2, 480.8–9, 481, 482.0, 482.30–2, 482.41–2, 482.83, 482.89–90, 483.8, 484.3, 485, 486, 487.0) or pulmonary effusion/ empyema (510.0, 510.9, 511.0–1, 511.8–9, 513).[12]

For children with multiple hospitalizations (13% of sample), 1 admission was randomly selected for inclusion. This method helped prevent findings from being heavily influenced by a small group of children experiencing a large number of admission or by 1 type of admission (eg, readmissions).

Exclusion Criteria—We excluded children who did not receive an antibiotic in the first 2 calendar days of admission to minimize the likelihood of including children with (1) nonbacterial pneumonia and (2) who were admitted for nonpneumonia diagnosis but treated for hospital-acquired pneumonia. Children transferred in from another hospital were excluded because records from their initial presentation including testing, treatment, and outcomes were not available in PHIS. Finally, children with a diagnosis of HIV or tuberculosis and children who received antiretroviral or antituberculosis therapy during hospitalization were excluded given expected differences in presentation, management, treatment, and outcomes[15] (Supplemental Figure 2).

Outcome Measures

The primary outcome was the presence of a pneumonia-associated complication during hospitalization. Local (eg, effusion), systemic (eg, acute respiratory failure), and metastatic (eg, meningitis) complications of pneumonia were identified using previously described *ICD-9-CM* codes.[16] Secondary outcomes were hospital resource utilization and mortality. Hospital resource utilization included length of stay (LOS) measured in billed hospital days, ICU transfer, all-cause readmission within 30 days of discharge,[17] and standardized total hospitalization costs.[18]

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Patient Demographics and Clinical Characteristics

Demographic and clinical characteristics that might differ in prevalence between children diagnosed with aspiration versus nonaspiration pneumonia were assessed, including age, gender, race/ethnicity, insurance, discharge disposition, NI category, presence of a complex chronic condition, assistance with medical technology, and presence of additional comorbidities.

Nine NI categories were assessed: (1) static neurologic disease, (2) progressive neurologic disease, (3) anatomic abnormality, (4) epilepsy, (5) genetic or metabolic condition, (6) cerebrovascular disease, (7) peripheral neurologic disease, (8) behavioral, and (9) not otherwise specified/other. These NI categories are not mutually exclusive (ie, patients may have diagnoses in multiple categories).

Complex chronic conditions (CCC)[19] are "any medical condition that can be reasonably expected to last at least 12 months (unless death intervenes) and to involve either several different organ systems or 1 system severely enough to require specialty pediatric care and probably some period of hospitalization in a tertiary care center."[20] We assessed type and number of CCCs endured by each child. The neurologic and neuromuscular CCC category was not examined because all children in our cohort had NI diagnoses. Medical technology included devices (eg, gastrostomy, tracheostomy) used to optimize children's health and functional status.[21] Additional comorbidities known to correlate with severity of NI in children (eg, gastroesophageal reflux, scoliosis) were also assessed.

Diagnostic Testing

As our focus on initial evaluation, we assessed testing that occurred in first 2 calendar days of admission. Laboratory testing, assessed with billing data, included complete blood count, C-reactive protein, erythrocyte sedimentation rate, blood gas, blood chemistry, coagulation studies, liver function studies, and microbiologic studies (ie, viral testing, blood cultures, respiratory cultures, and urine cultures). Imaging studies included chest radiography, ultrasonography, and computed tomography.

Treatment of Pneumonia

Empirical antibiotic therapy, β agonist therapy (eg, albuterol), systemic corticosteroids (eg, prednisolone), and inhaled corticosteroids (eg, fluticasone) were examined as treatments received in the first 2 calendar days of hospitalization. Empirical antibiotic therapy included oral and intravenous antibiotics aside from oral vancomycin and oral aminoglycosides, which are not adequately absorbed to effectively treat pneumonia. Antibiotics were classified and examined by antimicrobial spectra of activity against the most commonly recognized pathogens of aspiration and nonaspiration pneumonia: (1) *Streptococcus pneumoniae* (eg, aminopenicillins), (2) anaerobes (eg, fluoroquinolones), and (3) *Pseudomonas aeruginosa* (eg, fourth-generation cephalosporins).[22]

Statistical Analysis

Continuous data were described with median and interquartile ranges (IQR) given nonnormal distributions. Categorical data were described with counts and frequencies.

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Demographics, clinical characteristics, diagnostic testing, treatment, and outcomes were stratified by pneumonia diagnosis (aspiration and nonaspiration) and compared using χ^2 and Wilcoxon rank sum tests for categorical and continuous variables, respectively.

Generalized estimating equations, clustered on hospital, were derived to assess the independent effect of pneumonia diagnosis on outcomes of pneumonia-associated systemic complications, ICU transfer, and 30-day all-cause readmission while adjusting for important differences in demographic and clinical characteristics. Because LOS and costs had a nonnormal, exponential distribution, they were assessed with exponential regression that included a log link function and a random intercept for each hospital (to account for patient clustering).

Covariates were chosen a priori because of their clinical and biological relevance to exposure and outcomes: age, use of gastrointestinal and respiratory technology, nonneurologic CCC count, NI category, presence of additional comorbidities, and antimicrobial treatment. Each NI category and additional medical comorbidity was included in the models, thereby controlling for patients with multiple diagnoses (eg, 4 types of NI and 3 comorbidities). Moreover, presence of any pneumonia-associated complication was an additional covariate in models for utilization outcomes.

Generalized estimating equations results are presented with adjusted odds ratios (aOR) with 95% confidence interval (CI). LOS and cost results are presented as ratios of means (RoM) with 95% CI to depict relative differences in LOS or cost between all children within a hospital with aspiration versus nonaspiration pneumonia (eg, a RoM of 1.3 depicts a 30% longer LOS for children with aspiration pneumonia compared with those with nonaspiration pneumonia).

All analyses were performed with SAS v9.3 (SAS Institute, Cary, NC). $P < .05$ was considered statistically significant. Patients with missing data (<1% of all data) were removed from analysis. Cincinnati Children's Hospital Medical Center Institutional Review Board considered this study exempt as it used a de-identified, existing data set.

RESULTS

Study Cohort

Of the 27 455 children included, median age was 4 years (IQR 2–8), and 52.5% were male. Forty-seven percent were non-Hispanic white, 16.2% were non-Hispanic black, and 24.2% were Hispanic. Most children (54.6%) used public insurance (Table 1). Aspiration pneumonia was diagnosed in 9.7% ($n = 2659$) of the cohort.

Demographics and Clinical Characteristics

Compared with children diagnosed with nonaspiration pneumonia, children with aspiration pneumonia were older (median age 5 years [IQR 2–11] vs 4 years [IQR 2–8], $P < .001$] and used public insurance more often (62.0% vs 53.8%, $P < .001$; Table 1).

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Children diagnosed with aspiration pneumonia had a different profile of NI, with higher prevalence of epilepsy (56.4% vs 14.4%), genetic or metabolic conditions (23.9% vs 13.8%), and progressive neurologic disease (3.3% vs 0.7%), $P < .001$ for all.

Children diagnosed with aspiration pneumonia had a higher prevalence of CCCs (eg, gastrointestinal: 63.9% vs 17.7%, $P < .001$) and technology dependence (69.8% vs 21.8%, $P < .001$; Table 1). The presence of additional medical comorbidities was also more frequent in children diagnosed with aspiration pneumonia (eg, gastroesophageal reflux [42.9% vs 10.0%], $P < .001$; Table 1).

Diagnostic Testing

Children diagnosed with aspiration pneumonia were more likely than children with nonaspiration pneumonia to receive diagnostic laboratory tests (eg, complete blood count: 82.7% vs 68.8%, $P < .001$), with the exception of erythrocyte sedimentation rate (5.4% vs 5.6%, $P = .6$; Table 2). Children diagnosed with aspiration pneumonia were more likely to receive a chest radiograph (91.8% vs 86.1%) and less likely to receive chest computed tomography (1.2% vs 2.5%) or ultrasound (0.6% vs 1.8%), $P < .001$ for all (Table 2).

Treatment

Children diagnosed with aspiration pneumonia received a different profile of antibiotics than children with nonaspiration pneumonia (Table 2). The most common antimicrobial coverage for aspiration pneumonia were pneumococcal and anaerobic combined (68.4%) and then pneumococcal, anaerobic, and antipseudomonal combined (16.4%). Children with nonaspiration pneumonia most commonly received pneumococcal coverage alone (66.4%).

Children diagnosed with aspiration and nonaspiration pneumonia received inhaled β agonists (68.8% vs 68.4%, $P = .6$) and systemic steroids (0.3% vs 0.3%, $P = .9$) at similar rates. Children diagnosed with aspiration pneumonia were more likely to receive inhaled corticosteroids (44.5% vs 26.4%, $P < .001$; Table 2).

Clinical Outcomes and Utilization

Pneumonia-Associated Complications—Twenty-four percent of children experienced a pneumonia-associated complication. Systemic complications were most common (17.0%), followed by local (9.1%) and metastatic (0.1%) (Table 3). In multivariable analysis, children diagnosed with aspiration pneumonia were more likely to have systemic complications (aOR 1.2, 95% CI 1.1–1.3; Fig 1).

LOS—Median hospital LOS for the total cohort was 3 days (IQR 2–5; Table 3). In multivariable analysis, children diagnosed with aspiration pneumonia had a 20% longer LOS than children with nonaspiration pneumonia (RoM 1.2, 95% CI 1.2–1.3; Fig 1).

ICU Care—Fifteen percent of children required ICU admission with an additional 1.7% requiring ICU transfer after admission (Table 3). In multivariable analysis, children diagnosed with aspiration pneumonia had 40% greater odds of ICU transfer than children with nonaspiration pneumonia (aOR 1.4, 95% CI 1.1–1.9; Fig 1).

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Readmission—The 30-day readmission rate was 7.8% (Table 3). The most common readmission diagnoses were pneumonia (10.3%), aspiration pneumonia (5.9%), and asthma (2.3%). In multivariable analysis, children diagnosed with aspiration pneumonia had a 20% greater odds of readmission within 30 days than children with nonaspiration pneumonia (aOR 1.2, 95% CI 1.1–1.4; Fig 1).

Hospital Costs—Median hospitalization cost for the total cohort was $5509 IQR $3213–$11 522; Table 3). In multivariable analysis, hospitalization cost was 20% higher for children diagnosed with aspiration pneumonia compared with children with nonaspiration pneumonia (RoM 1.2, 95% CI 1.2–1.3; Fig 1).

Mortality.—Less than 1% of the cohort died during hospitalization. Children with aspiration pneumonia were more likely to die during hospitalization than children with nonaspiration pneumonia (1.7% vs 0.6%, $P < .001$). Due to small numbers, mortality was not assessed in multivariable analysis.

DISCUSSION

In this retrospective cohort of children with NI hospitalized for pneumonia, we observed differences in the characteristics, evaluation, treatment, and outcomes between diagnoses of aspiration and nonaspiration pneumonia. Children diagnosed with aspiration pneumonia were older, used public insurance more often, had a different NI profile (eg, a higher prevalence of epilepsy, progressive NI), and had more complex chronic conditions, more additional comorbidities, and more use of medical technology. These findings suggest that children with NI diagnosed with aspiration pneumonia had a higher severity of NI, medical complexity, and fragility. However, their higher complication rates, longer and costlier hospitalizations, and higher readmission rates were not fully explained by those attributes in multivariable analysis. These findings are important to consider as hospital clinicians move forward with subsequent investigations to optimize care and outcomes for children with NI hospitalized with pneumonia.

This retrospective study of administrative claims data are not positioned to verify with complete accuracy the type of pneumonia diagnosed by hospital clinicians. Although we used principal diagnosis to distinguish pneumonia type, validated clinical criteria for diagnosing aspiration pneumonia in children do not exist. The value of clinical signs and symptoms (eg, a history that includes a choking episode followed by fever and respiratory distress) or certain test results (eg, right upper lobe infiltration on chest radiograph) to diagnose aspiration pneumonia remain unknown. Aspiration can be silent, sans signs and symptoms, and it can affect different parts and sides of the lung depending on patient position during aspiration. Tests that might verify aspiration of saliva or gastric contents into the airway (eg, bronchoscopy or transtracheal mucous aspirate) are not commonly used in the setting of acute pneumonia. As a result, when caring for children with a higher severity of NI, some clinicians may be more likely to apply a diagnosis of and treat for aspiration pneumonia by subjective suspicion rather than affirmation from hard evidence. Prospective studies are needed to assess these issues and to determine how to best distinguish aspiration pneumonia in children with NI.

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Our findings complement a growing body of literature suggesting that health outcomes are worse and hospital resource use is higher in patients diagnosed with aspiration versus nonaspiration pneumonia.[7–11,13] Further investigation is needed to explain how much these findings are a manifestation of aspiration pathophysiology versus an artifact of making the diagnosis. For children truly experiencing aspiration, the penetration of oropharyngeal saliva or acidic gastric contents, along with enteric bacteria, into the airway can result in a higher severity of epithelial disruption, inflammation, impaired gas exchange, and prolonged healing than when the airway is exposed to exogenous bacteria alone.[23–25] For children not experiencing aspiration but diagnosed with it, the diagnosis might actually reflect a high-severity, nonaspiration bacterial pneumonia (eg, with sepsis or respiratory failure) that led to worse outcomes and more hospital resource use. We controlled for pneumonia severity in our multivariable analyses; it did not fully explain why children with NI diagnosed with aspiration experienced worse health outcomes. Nonetheless, applying the diagnosis of aspiration pneumonia might indicate a higher severity of illness that is unmeasurable with administrative data used in this study.

Little is known about how much airway injury, inflammation, and bronchospasm from aspiration or nonaspiration pneumonia in children with NI may be responsive to treatments such as inhaled β-agonists and inhaled or systemic corticosteroids. Use of β-agonists was common for children with both aspiration and nonaspiration pneumonia. Treatment with systemic corticosteroids was uncommon. Children with aspiration pneumonia were more frequently prescribed inhaled corticosteroids, which could reflect presence of underlying chronic lung disease and/or persistent asthma. The high rates of respiratory complications, including respiratory failure, experienced by children with aspiration pneumonia suggest that heightened attention and subsequent investigation to respiratory treatments and therapies intended to maximize airway patency, oxygenation, and ventilation may be warranted.

We observed substantial variation in antimicrobial coverage for children with aspiration pneumonia, which may reflect the paucity of information on which enteric bacteria are causative. Although aspiration pneumonia has traditionally been attributed to anaerobic bacteria, a study of 74 hospitalized children with aspiration pneumonia isolated 5 bacteria (a mixture of anaerobes and aerobes), on average from transtracheal aspirates.[26] In adult patients, although anaerobes occur in one-third of aspiration pneumonias, aerobic Gram-negative bacteria, including enteric bacteria (eg, *Escherichia coli* and *Pseudomonas* spp) and Gram-positive bacteria (eg, methicillin-sensitive and methicillin-resistant *Staphylococcus aureus*), are recovered more often (ie, in 50% of cultures).[27–30] We are aware of only 1 randomized controlled trial that compared effectiveness of antibiotic treatment in hospitalized children with aspiration pneumonia; no difference in effectiveness between penicillin G and clindamycin was found.[31]

Our study has several limitations in addition to those described earlier. Clinical data may be preferable to administrative data to identify children with NI and the types of pneumonia they encounter. Misclassification of pneumonia type using ICD-9-CM codes is possible because there is no “gold standard” for diagnosis of aspiration pneumonia.[3,27] Aside from use of technology assistance, PHIS administrative data are not equipped to distinguish

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granular grades of functional status (eg, ability to cough, chest wall control and strength) that might influence health outcomes with pneumonia in children with NI. Interpretation of ICU admission may be limited by variability of admission practices and policies between hospitals. PHIS does not include readmissions to a different hospital, which could have led to undercounting. Although children with NI predominately use children's hospitals,[1] results may not generalize to children with NI hospitalized with pneumonia at non–children's hospitals. We randomly selected for analysis hospitalizations in children with multiple admissions; using alternative methods could have led to different findings. In a post hoc analysis excluding children with multiple admissions, findings did not change. We limited our study to initial evaluation and treatment of pneumonia in children with NI; subsequent studies are needed to assess the clinical course throughout hospitalization including further tests and treatments.

Despite these limitations, we believe these findings highlight the serious health consequences of pneumonia that occur in children with NI. It is important that these consequences are discussed with families of children with NI, especially the high rates of complications (34%) and 30-day hospital readmission (18%) in children diagnosed with aspiration pneumonia. Yet there remains a need to understand (1) how to accurately distinguish pneumonia type; (2) which antibiotics are most effective; and (3) how bronchodilators, steroids, and other respiratory treatments can be leveraged to maximize pulmonary function. We hope our findings will prompt subsequent investigations to optimize treatment and outcomes in hospitalized children with NI diagnosed with pneumonia.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

FUNDING: Dr Thomson was supported by funds from the Academic Pediatric Association Young Investigator Award and from National Research Service Award T32HP10027–14. Jay Berry was supported by the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development (grant K23 HD058092) and the Agency for Healthcare Research and Quality (grant R21 HS023092).

ABBREVIATIONS

aOR	adjusted odds ratio
CCC	complex chronic condition
CRP	C-reactive protein
CI	confidence interval
ICD-9-CM	International Classification of Diseases, Ninth Revision, Clinical Modification
IQR	interquartile range
LOS	length of stay

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NI	neurologic impairment
PHIS	Pediatric Health Information System
RoM	ratio of means

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WHAT'S KNOWN ON THIS SUBJECT:

Children with neurologic impairment are frequently hospitalized with pneumonia. They are at high risk for aspiration from a variety of factors including underlying muscle weakness, gastroesophageal refl ux, and dysphagia.

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WHAT THIS STUDY ADDS:

Hospitalized children with neurologic impairment diagnosed with aspiration pneumonia experience more diagnostic testing, more systemic complications such as acute respiratory failure, longer hospitalizations, and more readmissions than when diagnosed with nonaspiration pneumonia.

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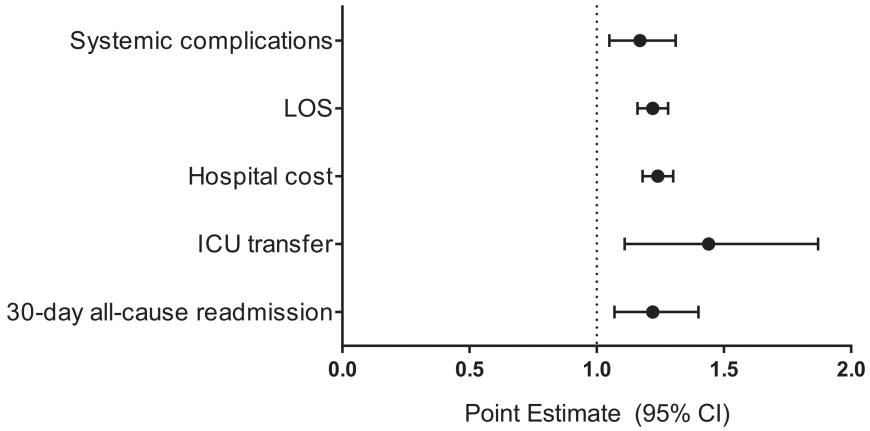

FIGURE 1.

Multivariable analysis of pneumonia-associated complications and hospital resource use in children with NI admitted for aspiration and nonaspiration pneumonia. Generalized estimating equations used to calculated aOR for systemic complications, ICU transfer, and 30-day all-cause readmission; exponential regression used to calculate adjusted RoM for outcomes of LOS and hospital cost. Models adjusted for age, NI category, nonneuromuscular CCC count, gastrointestinal and respiratory technology, noncomplex medical comorbidity antimicrobial treatment, and presence of any pneumonia-associated complication (for utilization outcomes).

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Pediatrics. Author manuscript; available in PMC 2019 January 07.

TABLE 1

Demographic and Clinical Characteristics of Children With Neurologic Impairment Admitted for Pneumonia to 40 Freestanding Children's Hospitals

Characteristic	Overall Cohort (n =27455)		Aspiration Pneumonia (*n*=2659)		Nonaspiration Pneumonia(*n* = 24796)		*P*[a]
	n	%	*n*	%	*n*	%	
Male	14 414	52.5	1445	54.3	12 969	52.3	.050
Age							
1–4 y	15 375	56.0	1252	47.1	14 123	57.0	<.001
5–9 y	6701	24.4	606	22.8	6095	24.6	
10–18 y	5379	19.6	801	30.1	4578	18.5	
Race/ethnicity							
Non-Hispanic white	13 020	47.4	1287	48.4	11 733	47.3	.320
Non-Hispanic black	4440	16.2	405	15.2	4035	16.3	
Hispanic	6647	24.2	621	23.4	6026	24.3	
Primary source of payment							
Government	14 999	54.6	1649	62.0	13 350	53.8	<.001
Private	9705	35.3	834	31.4	8871	35.8	
Other	2751	10.0	176	6.6	2575	10.4	
NI category							
Static neurologic disease	21 717	79.1	1742	65.5	19 975	80.6	<.001
Epilepsy	5073	18.5	1503	56.5	3570	14.4	<.001
Genetic or metabolic condition	4045	14.7	635	23.9	3410	13.8	<.001
Anatomic abnormality	3361	12.2	926	34.8	2435	9.8	<.001
Not otherwise specified/other	2205	8.0	716	26.9	1489	6.0	<.001
Peripheral neurologic disease	1373	5.0	251	9.4	1122	4.5	<.001
Behavioral	669	2.4	54	2.0	615	2.5	.200
Cerebrovascular disease	299	1.1	78	2.9	221	0.9	<.001
Progressive neurologic disease	252	0.9	88	3.3	164	0.7	<.001
CCC							
Gastrointestinal	6092	22.2	1699	63.9	4393	17.7	<.001
Congenital/genetic defect	5187	18.9	974	36.6	4213	17.0	<.001
Respiratory	2780	10.1	481	18.1	2299	9.3	<.001

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Characteristic	Overall Cohort (n =27455)		Aspiration Pneumonia (*n*=2659)		Nonaspiration Pneumonia(*n* = 24796)		*P*[a]
	n	%	*n*	%	*n*	%	
Cardiovascular	2260	8.2	348	13.1	1912	7.7	<.001
Metabolic	1239	4.5	232	8.7	1007	4.1	<.001
Neonatal	1182	4.3	222	8.3	960	3.9	<.001
Hematology/immunodeficiency	870	3.2	58	2.2	812	3.3	.002
Renal	741	2.7	123	4.6	618	2.5	<.001
Malignancy	670	2.4	79	3.0	591	2.4	.060
Transplant	320	1.2	20	0.8	300	1.2	.040
Nonneurologic CCC count							
0	15 138	55.1	372	14.0	14 766	59.5	<.001
1	4131	15.0	358	13.5	3773	15.2	
2+	8186	29.8	1929	72.5	6257	25.2	
Assistance with medical technology	7261	26.4	1856	69.8	5405	21.8	<.001
Gastrointestinal	5929	21.6	1692	63.6	4237	17.1	<.001
Respiratory	1898	6.9	311	11.7	1587	6.4	<.001
Neurologic/neuromuscular	1179	4.3	285	10.7	894	3.6	<.001
Cardiovascular	204	0.7	29	1.1	175	0.7	.030
Renal	143	0.5	23	0.9	120	0.5	.009
Other	872	3.2	160	6.4	703	2.8	<.001
Noncomplex medical comorbidities							
Reflux	3629	13.2	1142	42.9	2487	10.0	<.001
Constipation	1685	6.1	365	13.7	1320	5.3	<.001
Scoliosis	1578	5.7	427	16.4	1151	4.6	<.001
Osteopenia/osteoporosis	328	1.2	90	3.4	238	1.0	<.001
Diabetes insipidus	166	0.6	38	1.4	128	0.5	<.001

[a] *P* value for χ^2 test for categorical variables and for Wilcoxon rank sum test for continuous variables.

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TABLE 2

Diagnostic Testing and Treatment Within 48 Hours of Admission in Children With NI Hospitalized for Pneumonia

Characteristic	Overall Cohort (*n*= 27455)		Aspiration Pneumonia (*n* =2659)		Nonaspiration Pneumonia (*n*= 24796)		*P*[a]
	n	%	*n*	%	*n*	%	
Laboratory Testing							
Complete blood count	19 262	70.2	2198	82.7	17 064	68.8	<.001
Blood culture	16 041	58.4	1779	66.9	14 262	57.5	<.001
Chemistry profile	11967	43.6	1522	57.2	10 445	42.1	<.001
Viral study	10 481	38.2	1091	41.0	9390	37.9	.001
C-reactive protein	7277	26.5	780	29.3	6497	26.2	.001
Blood gas	7166	26.1	1220	45.9	5946	24.0	<.001
Urine culture	4136	15.1	732	27.5	3404	13.7	<.001
Respiratory culture	2157	7.9	414	15.6	1743	7.0	<.001
Erythrocyte sedimentation rate	1544	5.6	144	5.4	1400	5.6	.620
Coagulation study	1492	5.4	234	8.8	1258	5.1	<.001
Liver function test	645	2.3	126	4.7	519	2.1	<.001
Radiographic imaging							
Chest radiograph	23 793	86.7	2440	91.8	21 353	86.1	<.001
Chest computed tomography	650	2.4	33	1.2	617	2.5	<.001
Chest ultrasound	453	1.6	15	0.6	438	1.8	<.001
Treatment							
Empirical antimicrobial coverage							
Pneumococcal	16 777	61.1	303	11.4	16 474	66.4	<.001
Pneumococcal and anaerobic	6107	22.2	1820	68.4	4287	17.3	
Other combinations	2509	9.1	99	3.7	2410	9.7	
Pneumococcal, anaerobic, and antipseudomonal	2062	7.5	437	16.4	1625	6.6	
Adjunct therapy							
Inhaled β agonist	18 784	68.4	1830	68.8	16954	68.4	.640
Inhaled corticosteroids	7737	28.2	1182	44.5	6555	26.4	<.001
Systemic steroids	78	0.3	8	0.3	70	0.3	.860

[a] *P* value for χ^2 test for categorical variables and for Wilcoxon rank sum test for continuous variables.

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TABLE 3

Bivariable Analysis of Pneumonia-Associated Complications and Hospital Resource Use in Children with NI Admitted for Aspiration and Nonaspiration Pneumonia

Outcome	Overall Cohort (*n*= 27455)		Aspiration Pneumonia(*n* = 2659)		Nonaspiration Pneumonia(*n*= 24 796)		*P*[a]
	n	%	*n*	%	*n*	%	
Pneumonia-associated complications	6594	24.0	5621	22.7	973	36.3	<.001
Any local	2490	9.1	137	5.2	2353	9.5	<.001
Empyema	2432	8.9	132	5.0	2300	9.3	<.001
Lung abscess	240	0.9	9	0.3	231	0.9	.002
Bronchopleural fistula	36	0.1	1	0.0	35	0.1	.160
Necrotizing pneumonia	15	0.1	0	0.0	15	0.1	.210
Any systemic	4667	17.0	903	34.0	3764	15.2	<.001
Acute respiratory failure	4554	16.6	884	33.2	3670	14.8	<.001
SIRS/sepsis	341	1.2	74	72.8	267	1.0	<.001
ECMO	32	0.1	4	0.2	28	0.1	.590
Hemolytic uremic syndrome	16	0.1	0	0.0	16	0.1	.190
Any metastatic	37	0.1	7	0.3	30	0.1	.060
Meningitis	7	0.0	0	0.0	7	0.0	.390
CNS abscess	4	0.0	1	0.0	3	0.0	.300
Mastoiditis	1	0.0	1	0.0	0	0.0	.002
Pericarditis	8	0.0	1	0.0	7	0.0	.790
Endocarditis	3	0.0	0	0.0	3	0.0	.570
Osteomyelitis	13	0.0	5	0.2	8	0.0	<.001
Septic arthritis	1	0.0	0	0.0	4	0.0	.510
LOS, median d, IQR	3	2–5	5	3–10	3	2–5	<.001
30-d all-cause readmission rate	2141	7.8	463	17.4	1678	6.8	<.001
Intensive care							
Admission	4265	15.5	761	28.6	3504	14.1	<.001
Transfer	479	1.7	115	4.3	364	1.5	<.001
Cost, $, median, IQR	5509	3213–1 1 522	11594	5841–25562	5162	3080–10249	<.001
Death	201	0.7	46	1.7	155	0.6	<.001

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ECMO, extracorporeal membrane oxygenation; SIRS, systemic inflammatory response syndrome.

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