Diagnostic Testing and Hospital Outcomes of Children with Neurologic Impairment and Bacterial Pneumonia

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Objective To assess hospital-level variability in diagnostic testing and outcomes for children with neurologic impairment hospitalized with pneumonia.

Study design A retrospective cohort study of 27 455 children ages 1-18 years with neurologic impairment hospitalized with pneumonia at 39 children's hospitals. K-means clustering was used to assign each hospital to 1 of 3 groups (termed A, B, and C) based on similar diagnostic testing patterns. Outcomes of hospital-level median length of stay (LOS), 30-day readmissions, and pneumonia-associated complications were compared while controlling for patient differences.

Results Overall, 48.5% had comorbid complex chronic conditions, and 25.4% were assisted with medical technology. Outcomes and diagnostic testing varied across hospitals: median hospital-level LOS, 3.2 days (IQR 2.8-3.8); median readmission, 8.4% (IQR 6.8,-10.0); and median pneumonia-associated complication rate, 23.1% (IQR 18.7-26.8). Despite similar populations, hospitals in group A tended to perform fewer tests than those in groups B and C. Across hospital groups, there was a significant difference in adjusted readmission rates (group A 7.2%, group B 9.0%, group C 7.7%, $P = .003$). There was no significant difference in adjusted median LOS (group A 3.4 days, group B 3.2 days, group C 3.3 days, $P = .3$) or adjusted pneumonia-associated complication rates (group A 22.5%, group B 22.5%, group C 25.0%, $P = .6$).

Conclusions For children with neurologic impairment hospitalized with pneumonia, across hospital differences in diagnostic testing were not associated with clinically meaningful differences in outcomes. High-utilizing hospitals may be able to decrease diagnostic testing for children with neurologic impairment hospitalized with pneumonia without adversely impacting outcomes. *(J Pediatr 2016;178:156-63).*

Children with neurologic impairment have functional and or intellectual impairments that result from a variety of neurologic diseases. These children experience frequent, lengthy, and expensive hospitalizations and account for an increasing and disproportionate amount of inpatient hospital resources.[1] Pneumonia is one of the most common reasons for hospitalization, the most common reason for admission to an intensive care unit (ICU), and the most common cause of death in this population.[1-4]

Unlike pneumonia in otherwise healthy children, sparse evidence exists to guide diagnostic testing or management for children with neurologic impairment hospitalized with pneumonia. Clinicians instead use personal experience, local practice culture, and parental preference to guide their decision-making.[5] Children with complex chronic conditions hospitalized with pneumonia receive more intensive management, yet have worse outcomes compared with otherwise healthy children.[6] Little is known about current hospital management and outcomes of pneumonia in the population of children with neurologic impairment. Prior studies in otherwise healthy children hospitalized with pneumonia have demonstrated variation in diagnostic testing, treatment, and outcomes across hospitals.[7,8] In fact, increased diagnostic testing has been associated with increased hospitalization rates among those evaluated in the emergency department[8] and longer hospital length of stay (LOS) among those requiring admission.[7] The objectives in this study of children with neurologic impairment hospitalized with bacterial pneumonia were to assess the variability in outcomes and diagnostic testing across hospitals, and to determine the association between hospital-level diagnostic test utilization and outcomes.

CBC	Complete blood count
CCC	Complex chronic condition
ICD-9-CM	*International Classification of Diseases, Ninth Revision, Clinical Modification*
ICU	Intensive care unit
LOS	Length of stay
PHIS	Pediatric Health Information System

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Methods

This multicenter, retrospective, cohort study included data from the Pediatric Health Information System (PHIS), an administrative database of 45 not-for-profit, tertiary care, US pediatric hospitals affiliated with the Children's Hospital Association (Overland Park, Kansas). 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, which include laboratory studies and radiologic imaging. Encrypted medical record numbers permit identification of patients across multiple visits to the same hospital. Data quality and reliability are assured through Children's Hospital Association and participating hospitals. The 39 hospitals that provided data to PHIS throughout the entire study period were included in this study.

Hospitalizations of children 1-18 years of age who were discharged between July 1, 2007, and June 30, 2012, were included if they had a neurologic impairment ICD-9-CM diagnosis code[1] and a principal discharge diagnosis indicative of bacterial pneumonia.[9] Neurologic impairment was defined as functional and/or intellectual impairment resulting from a neurologic disease (eg, cerebral palsy, epilepsy) using a previously defined set of 606 ICD-9-CM diagnosis codes.[1] Infants <1 year of age were excluded as many neurologic impairment diagnoses (eg, cerebral palsy) are not assigned until an older age. As in our prior work,[10] hospitalizations for pneumonia were identified based on previously validated methods using principal ICD-9-CM diagnosis codes 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) and pulmonary effusion/empyema (510.0, 510.9, 511.0-1, 511.8-9, 513),[9] as well as ICD-9-CM codes for aspiration pneumonia (507.x). For children with multiple hospitalizations, 1 admission was randomly selected for inclusion to minimize the chance of biasing the findings with a small group of children who experienced a large number of admissions.

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 nonbacterial pneumonia. This approach also minimized the inclusion of children who were admitted for reasons other than pneumonia, but then were treated and coded for pneumonia acquired during their hospitalization. Children transferred in from another hospital were excluded as records from their initial presentation including testing, treatment, and outcomes were not available in PHIS. Finally, children with a diagnosis of HIV, Pneumocystis pneumonia, or tuberculosis and children who received antiretroviral or antituberculosis therapy during hospitalization were excluded given expected differences in presentation, management, treatment, and outcomes (**Figure 1**; available at www.jpeds.com).[11]

Outcome Measures

Outcome measures in this study were hospital-level LOS measured in hospital days, all-cause 30-day hospital readmission (ie, readmission for any cause and for any admission type, including observation),[12] and pneumonia-associated complication rate. Pneumonia-associated complications (local [eg, effusion], systemic [eg, acute respiratory failure], and metastatic [eg, meningitis]) were examined using previously described ICD-9-CM codes.[13]

Diagnostic Test Utilization

As we aimed to examine only testing performed in the initial diagnosis and management, we examined only those tests obtained in the first 2 calendar days of admission. Diagnostic tests examined include laboratory studies and radiologic imaging, and were based on billing data in PHIS. Hospital-level diagnostic test utilization was defined as the percent of patients at each hospital who had each test ordered in the first 2 calendar days of admission. Laboratory studies included complete blood count (CBC), C-reactive protein, blood gas, blood chemistry profile, and microbiologic studies of viral testing, blood culture, and respiratory culture. Imaging studies included chest radiograph.

Patient Case-Mix

To compare patient case-mix across hospitals, we examined underlying neurologic disease, as well as medical comorbidities associated with severity of neurologic impairment and severity of acute illness. Nine neurologic impairment 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.[1,10] These neurologic impairment categories are not mutually exclusive (ie, patients may have diagnoses in multiple categories). Underlying medical comorbidities included the number of non-neurologic complex chronic conditions (CCCs)[14] endured by each patient and assistance with medical technology. CCCs 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 one system severely enough to require specialty pediatric care and probably some period of hospitalization in a tertiary care center."[15] The neurologic and neuromuscular CCC category was not included in the CCC count as all patients in our cohort had diagnoses of neurologic impairment. Medical technology assistance (eg, tracheostomy) was defined using the medical technology or device subcategory within relevant CCC categories.[14] Severity of acute illness was examined by the percent of patients who required mechanical ventilation, vasopressor use, or ICU admission.

Statistical Analyses

Continuous data were described with median and IQR attributable to non-normal distribution. Categorical data were described with frequencies and percentages. Outcomes of LOS, 30-day all-cause hospital readmission rate, and pneumonia-associated complication rate were compared across hospitals. Correlation of LOS and 30-day all-cause hospital