

Variation in Diagnostic Testing and Hospitalization Rates in Children With Acute Gastroenteritis

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Acute gastroenteritis (AGE) remains a major cause of childhood morbidity and mortality in the United States. The routine use of vaccines targeting rotavirus, the most common cause of pediatric AGE, has decreased all-cause AGE emergency department (ED) visits and hospitalizations.¹ However, the burden of pediatric AGE remains substantial. With annual hospitalization rates of 3 to 5 per 1000 US children <5 years of age, AGE remains among the top 10 reasons for pediatric hospitalization nationwide.^{1,2} The financial burden of ED care and hospitalization alone accounts for >\$350 million in costs annually.³

Care for uncomplicated AGE is largely supportive, and guidelines from the American Academy of Pediatrics and other international organizations emphasize conservative management and discourage routine diagnostic testing for AGE, with or without dehydration.⁴⁻⁶ Yet there continues to be wide variation in AGE management among individual providers and hospitals in the United States and abroad.^{7,8} Studies in children with acute respiratory illness show similar variation in care that is associated with important outcome differences, with higher resource utilization linked to higher rates of hospitalization and longer hospital length of stay (LOS), irrespective of the severity of illness.^{9,10} Whether similar associations exist between resource utilization and outcomes in children with AGE is largely unexplored.

With the use of data from 34 US children's hospitals, we sought to characterize hospital-level variation in diagnostic testing and hospitalization rates in children with AGE presenting for emergency care. We also examined associations between diagnostic testing and rates of hospitalization.

METHODS

Study Design and Data Source

We conducted a multicenter, retrospective study in children with AGE evaluated at 1 of 34 US children's hospitals that contribute data to the Pediatric Health Information System (PHIS) administrative database (Children's Hospital Association, Overland Park, KS). The PHIS database contains patient demographic characteristics and billed

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Dr Lind conceptualized and designed the study, assisted with data interpretation, and drafted the initial manuscript; Dr Hall conceptualized and designed the study, carried out the initial analyses and assisted with data interpretation, and reviewed and revised the manuscript; Drs Arnold, Browning, Johnson, Plemmons, Zaman, and Williams conceptualized and designed the study, assisted with data interpretation, and reviewed and revised the manuscript; and all authors approved the final manuscript as submitted.

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utilization data for ED, inpatient, and ambulatory surgery encounters at 43 tertiary children's hospitals in 18 states and the District of Columbia. The PHIS contains up to 41 diagnoses from *International Classification of Diseases, Ninth Revision, Clinical Modification*, and 41 procedure codes from *International Classification of Diseases, Ninth Revision, Clinical Modification*, per encounter. Billing charges are mapped to a common set of clinical transaction codes, which include imaging studies, clinical services, laboratory tests, pharmacy, supplies, and room charges. This study was deemed exempt by the institutional review board at Vanderbilt.

Study Population

Children ≥ 90 days and < 6 years of age evaluated in the ED between January 1, 2008, and December 31, 2014, and discharged from the ED or an inpatient unit

with (1) a principal discharge diagnosis of viral gastroenteritis (008.8) or rotavirus (008.61) or (2) a principal discharge diagnosis of dehydration (276.51) with a secondary diagnosis of viral gastroenteritis or rotavirus were eligible for inclusion. We focused on young children because AGE disease burden is highest in this age group. Children transferred from another hospital, those with ≥ 1 complex chronic conditions,¹¹ and those admitted to intensive care were excluded. Children < 90 days of age and those with complex chronic conditions were excluded because it is likely that decisions regarding hospitalization, use of diagnostic testing, and/or length of hospitalization differ from those for children > 3 months of age without ≥ 1 of these conditions. We also excluded data from 8 PHIS hospitals with < 2 years of complete ED and inpatient data during the study period; 30 of the 34 included

hospitals (85.7%) had complete data for the entire study period.

Outcome Measures

All outcomes were evaluated at the hospital level. The primary exposure was the average per-patient diagnostic testing count at each hospital, and the primary outcome was hospital admission, expressed as a percentage of all ED visits. Additional outcomes included inpatient LOS (median), ED revisits within 3 days of discharge (%), hospital readmission within 7 days of discharge (%), annual costs (\$US) attributed to diagnostic testing, and costs attributed to hospitalizations exceeding that expected on the basis of each hospital's case mix. Annual costs were estimated from charges by using hospital-specific cost-to-charge ratios and adjusted for hospital location by using the Centers for Medicare and Medicaid Services' price/wage index.¹²

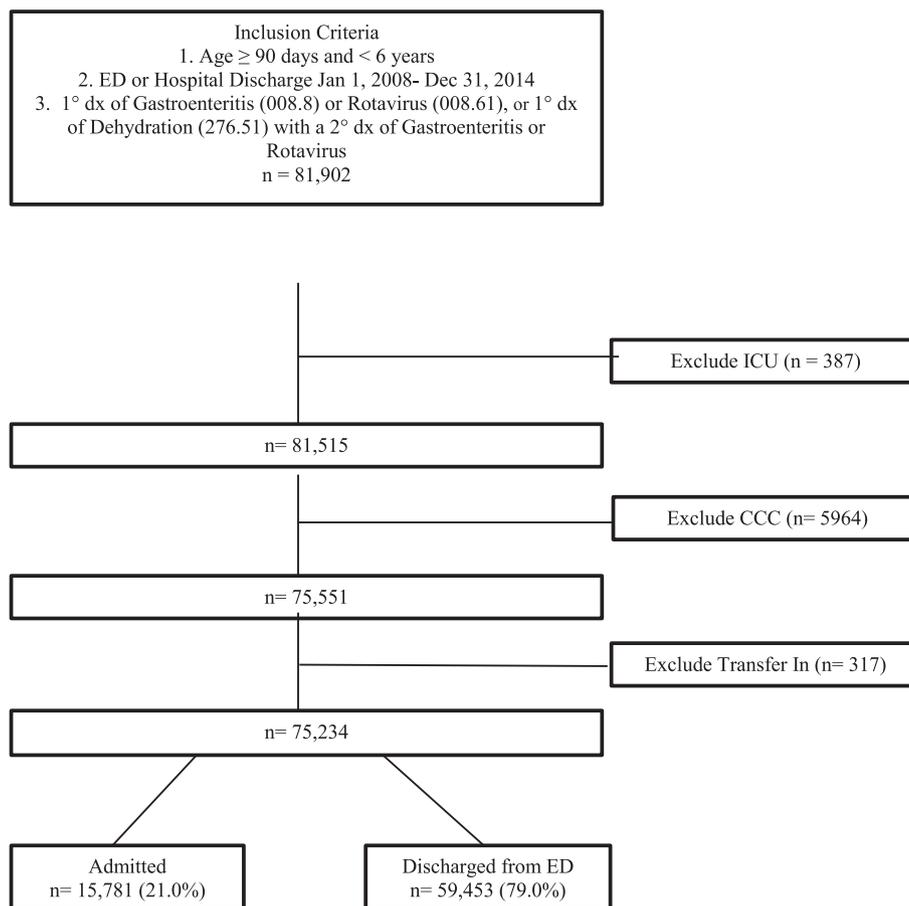


FIGURE 1 Cohort diagram. CCC, complex chronic condition; dx, diagnosis; 1°, primary; 2°, secondary.

Diagnostic Studies

The primary exposure variable was diagnostic testing. Diagnostic studies included stool studies (rotavirus testing and stool cultures), complete blood count (CBC), chemistry panels (basic metabolic panel, complete metabolic panel, and electrolyte panel), and any imaging. For hospitalized children, data were limited to the first hospital day to approximate studies performed as part of the initial diagnostic evaluation. For all observations, only the first instance of a diagnostic test in each of the 4 categories (stool studies, CBC, chemistry panels, and any imaging) was counted. For each hospital, we calculated a mean testing count after summing the number of tests at the patient level, for a maximum testing count of 4.

Covariates

Demographic variables included age, sex, race/ethnicity, payor (government, private, and other), season, and census region of the hospital. Illness severity was classified by using the All Patient-Refined Diagnosis-Related Groups (APR-DRG) version 24 severity of illness (SOI) classification. Because severity groups are not comparable across APR-DRGs, we used the severity weights assigned to each APR-DRG severity level that are available in the PHIS (applies to both observation status and inpatient stays). The weights were developed by Truven Health Analytics (Ann Arbor, MI), the data vendor for the PHIS database, by using their national normative pediatric database and are calculated as the average charge for patients in a specific APR-DRG/SOI combination divided by the average for all discharges, regardless of their APR-DRG/SOI assignment. This method is similar to the derivation of weights used by Medicare in their Prospective Payment System.¹³

Analysis

Categorical patient characteristics were summarized with frequencies and percentages and then compared between ED discharges and hospital admissions by using χ^2 tests. For continuous variables,

we used medians with interquartile ranges (IQRs) with Wilcoxon rank-sum tests. We risk-adjusted all hospital-level measures including the following: (1) the mean testing count, (2) the percentage admitted, (3) inpatient LOS, (4) the return rate within 3 days after an ED discharge, and (5) the return rate within 7 days of an inpatient stay with severity weights, age, and payor by using generalized linear mixed-effects models with a random hospital intercept. We assessed the relationship between these measures at the hospital level by using Pearson's correlation coefficient. We also repeated the primary analysis comparing mean testing count with the percentage admitted after excluding children <1 year of age because these children may be more likely to be hospitalized.

For the potential cost savings from eliminating stool studies, CBCs, chemistry panels, and any imaging, we totaled each hospital's cost for these tests and annualized. Generalized linear mixed-effects models provided us with the expected and observed number of admissions for each hospital on the basis of their unique distribution of cases by severity, age, and payor. For each hospital in which the observed admissions exceeded the expected value, we calculated the difference between these values to estimate the number of admissions above the expected for each hospital. We computed the total potential cost savings for each hospital by taking this value multiplied by the difference between the hospital's median cost of a hospitalization and the hospital's median cost of an ED

TABLE 1 Characteristics of the Study Population

	Overall (N = 75 234)	ED Discharge (n = 59 453)	Admitted (n = 15 781)	P
Age, median (IQR), mo	21 (11–38)	22 (11–38)	19 (10–34)	<.001
Sex, n (%)				
Male	40 946 (54.4)	32 449 (54.6)	8497 (53.8)	.195
Female	34 286 (45.6)	27 002 (45.4)	7284 (46.2)	—
Race, n (%)				
NH white	24 975 (33.2)	16 572 (27.9)	8403 (53.2)	<.001
NH black	22 901 (30.4)	20 236 (34)	2665 (16.9)	—
Hispanic	19 232 (25.6)	16 219 (27.3)	3013 (19.1)	—
Asian	1701 (2.3)	1320 (2.2)	381 (2.4)	—
Other	6425 (8.5)	5106 (8.6)	1319 (8.4)	—
Season, n (%)				
Spring	23 176 (30.8)	17 616 (29.6)	5560 (35.2)	<.001
Summer	13 865 (18.4)	11 104 (18.7)	2761 (17.5)	—
Fall	16 193 (21.5)	13 297 (22.4)	2896 (18.4)	—
Winter	22 000 (29.2)	17 436 (29.3)	4564 (28.9)	—
Payor, n (%)				
Government	48 516 (64.5)	40 352 (67.9)	8164 (51.7)	<.001
Private	22 533 (30)	16 151 (27.2)	6382 (40.4)	—
Other	4185 (5.6)	2950 (5)	1235 (7.8)	—
Census region, n (%)				
Northeast	12 518 (16.6)	10 333 (17.4)	2185 (13.8)	<.001
South	24 427 (32.5)	18 389 (30.9)	6038 (38.5)	—
North central	22 113 (29.4)	18 872 (31.7)	3241 (20.5)	—
West	16 176 (21.5)	11 859 (19.9)	4317 (27.4)	—
LOS, median (IQR)	—	—	1 (1–2)	—
Cost, median (IQR), \$	295 (148–787)	225 (134–372)	2527 (1779–3806)	<.001

Characteristics of patients with AGE evaluated at 34 US children's hospitals, January 1, 2008, through December 31, 2014. NH, non-Hispanic.

visit for children in the cohort. Finally, we divided the total potential cost savings by the number of study years to determine the annual potential cost savings (unadjusted for inflation). All analyses were performed by using SAS version 9.4 (SAS Institute, Cary, NC), with $P < .05$ being considered statistically significant.

RESULTS

Study Population

During the study period, 75 234 ED visits for AGE were eligible for inclusion (Fig 1). Of these, 21.0% patients were hospitalized. The median age of included children was 21 months (IQR: 11–38 months), 54.4% of the patients were male, and 64.4% had

government insurance. Median costs overall were \$225 (IQR: \$134–\$372) for children discharged from the ED and \$2527 (IQR: \$1779–\$3806) for hospitalizations (Table 1).

Variation in Diagnostic Studies

Diagnostic studies were uncommon among children discharged from the ED (16.5% had

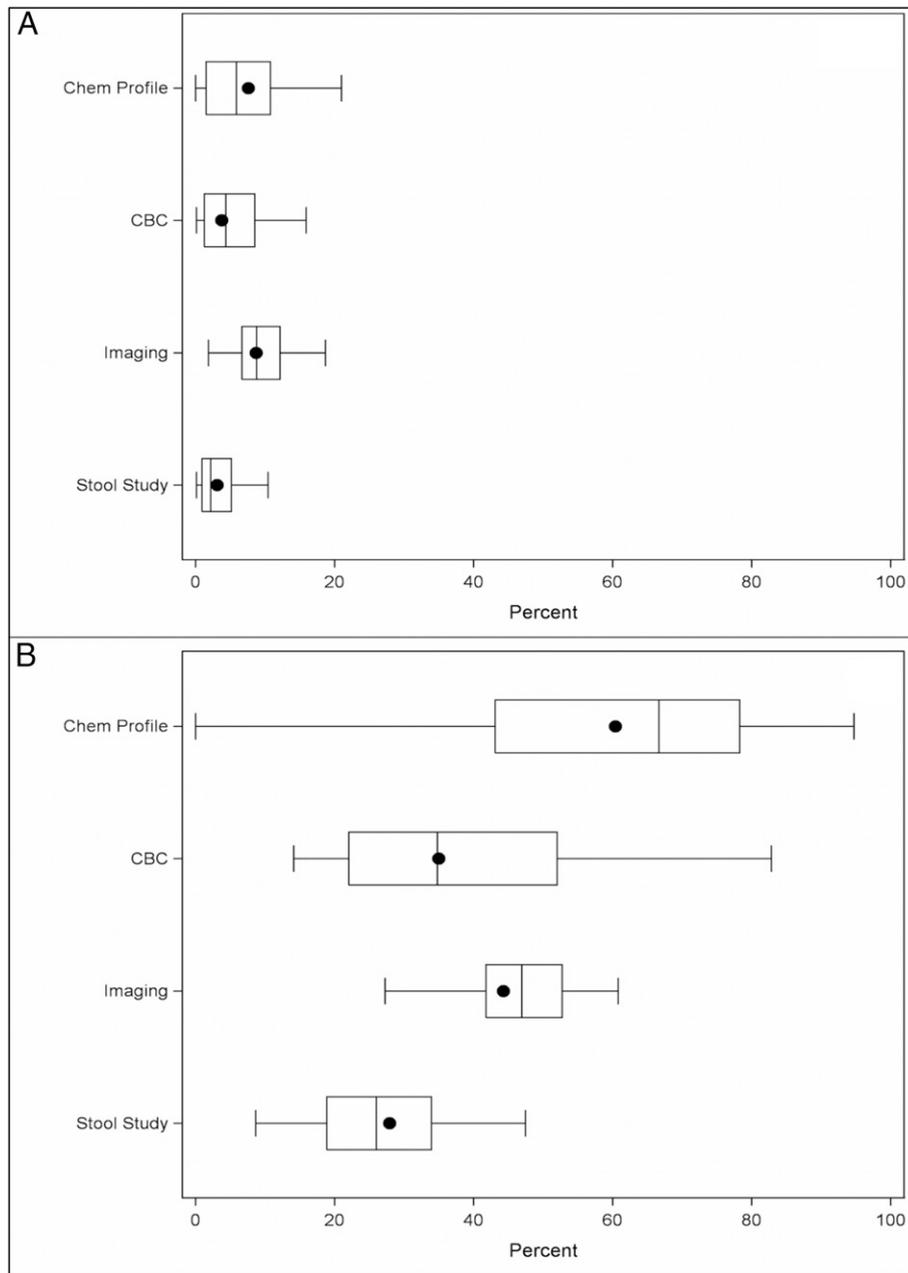


FIGURE 2 Hospital-level variation in diagnostic testing for children with AGE evaluated in the ED and discharged from (A) or admitted to (B) the hospital. Box plots represent the hospital-level median (vertical line within each box), IQR (box ends), and 1.5 times the IQR (whiskers) proportion of patients at each hospital receiving diagnostic testing. Solid circles represent patient-level medians across all hospitals. Chemistry profiles include BMP and CMP; stool studies include rotavirus antigen, stool cultures, and *Clostridium difficile* antigen. Chem Profile, chemistry profile.

≥1 diagnostic study performed). Among hospitalized children, 13 342 (84.5%) had ≥1 diagnostic studies performed: chemistry panels were most common (60.4%), followed by imaging (44.3%), CBCs (35.0%), and stool studies (27.9%; Fig 2). At the hospital level, substantial variation was found in the utilization of diagnostic studies in both children discharged from the ED and those admitted to the hospital. The greatest variation occurred in the admission group in the utilization of chemistry panels (56.4%; IQR: 30.6%–77.2%) and CBCs (34.8%; IQR: 22.4%–50.9%) (Fig 2).

Hospital-Level Utilization of Diagnostic Studies and Patient Disposition

Marked variation was noted across hospitals in the risk-adjusted percentage of children hospitalized for AGE (median: 21.5%; range: 5.6%–49.4%) (Fig 3). Hospital-level mean testing count was strongly correlated with the percentage of children hospitalized for AGE at each hospital ($r = 0.73, P < .001$). Results were unchanged

when excluding children <1 year of age ($r = 0.75, P < .001$). In contrast, the mean testing count was not correlated with return visits within 3 days for children discharged from the ED ($r = 0.21, P = .235$), nor was it correlated with hospital LOS ($r = -0.04, P = .804$) or return visits within 7 days ($r = 0.03, P = .862$) for hospitalized children (Fig 4).

Costs of Diagnostic Studies and Potential Cost Savings From Reducing Admissions

The total annualized cost of diagnostic studies for all hospitals was \$803 962 (hospital-level median: \$17 922; IQR: \$14 197–\$30 277). For hospitals whose risk-adjusted admission percentage was higher than expected, we calculated the potential cost savings if admissions above the expected were eliminated. This resulted in an annualized potential cost savings of \$672 599 (hospital-level median: \$38 369; IQR: \$11 483–\$51 388). Combined, the annualized costs of diagnostic studies plus costs related

to admissions above the expected for AGE across all hospitals totaled \$1 476 560.

DISCUSSION

We identified substantial hospital-level variation in diagnostic test utilization and hospital admission rates in children with AGE presenting for emergency care across 34 US children's hospitals. Importantly, higher diagnostic test utilization was strongly correlated with increased hospitalization rates but was not associated with differences in 3-day ED revisit rates, hospital LOS, or hospital readmissions, after controlling for cofactors associated with illness severity. Our findings suggest that reducing diagnostic testing for AGE in the ED may lead to reductions in resource utilization and potentially hospitalization rates without adverse consequences.

The measurement of electrolytes was the most common diagnostic test performed in our study. These tests were performed in the majority of children hospitalized with AGE, despite national guidelines

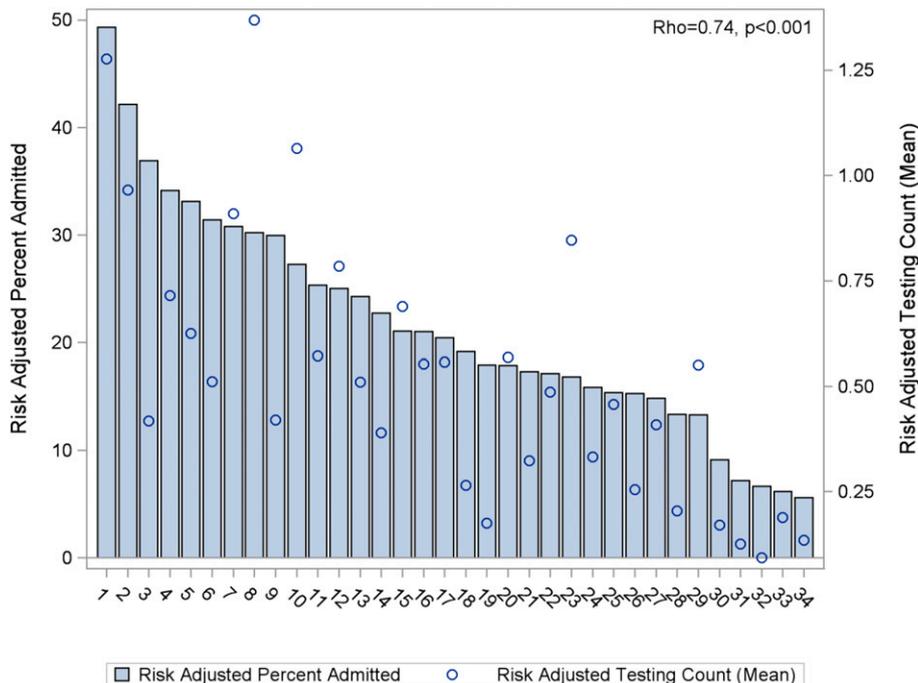


FIGURE 3 Association between hospital-level diagnostic testing and admission percentage for patients with AGE at 34 US children's hospitals. The risk-adjusted mean testing count (open circles; right y axis) is strongly correlated with the risk-adjusted percentage admitted (bars; left y axis) ($\rho = 0.74, P < .001$). Each observation (bars and open circles) represents a single hospital and is adjusted for age, payor, and severity.

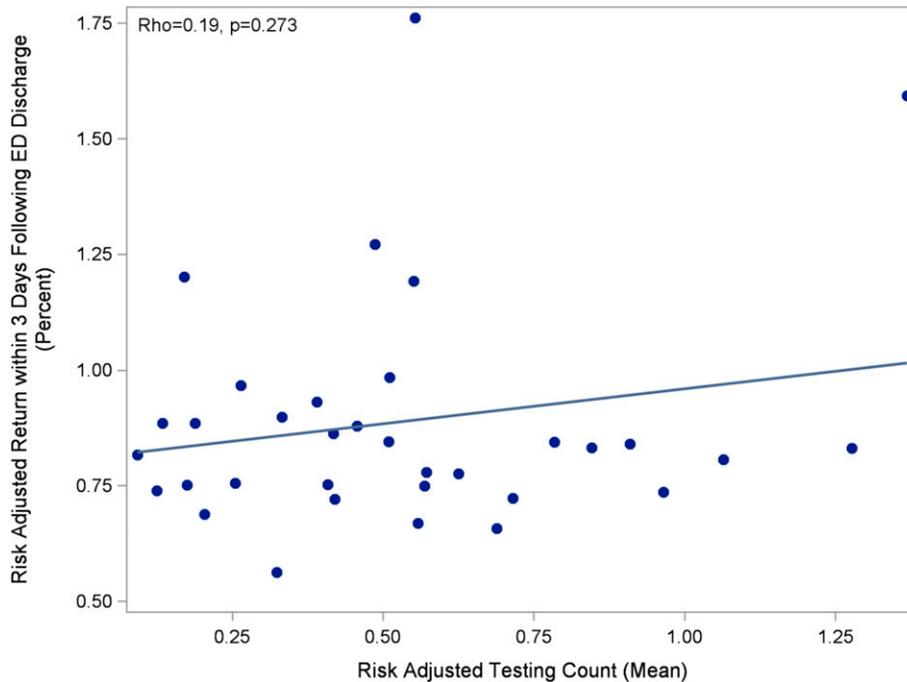


FIGURE 4 Association between hospital-level diagnostic testing and 3-day ED return visits at 34 US children's hospitals. Mean testing count is not correlated with 3-day ED return visits ($\rho = 0.19$, $P = .273$). Each solid circle represents a single hospital. Estimates were adjusted for age, payor, and severity.

discouraging their use except in cases of severe dehydration or an otherwise complicated course.⁴ Furthermore, electrolytes are poor predictors of dehydration when compared with the clinical examination.¹⁴ Similarly, diagnostic imaging studies and other laboratory studies, which are not routinely recommended by national guidelines, were performed often at some hospitals and rarely at others in our study. Reasons for these discrepancies and the wide variation across hospitals are unclear. A Canadian study examining all-cause ED visits noted important provider variation among 81 ED providers at 2 pediatric institutions in the utilization of common ED resources, including laboratory tests, imaging, and intravenous hydration.⁷ Hospitalization rates also varied by three- to eightfold. Furthermore, increased resource utilization was correlated with increased LOS but did not reduce ED revisits. Although we were unable to examine individual provider behavior, we hypothesize that provider preference is an important driver of the hospital-level differences noted in our study.

Higher test utilization was associated with increased hospitalization rates but did not reduce ED revisits or secondary hospitalizations, after controlling for cofactors associated with illness severity. This finding suggests that diagnostic testing may influence decisions around hospitalization but has little effect on patient outcomes. If test results are abnormal, physicians are less likely to discharge a patient home from the ED.¹⁵ Even mild abnormalities in test results may influence decision-making, leading to a subsequent cascade of repeat laboratory testing and hospitalization.¹⁶ Unnecessary hospitalization exposes children to potentially avoidable harms and is an excessive emotional and financial burden on families compared with home care.¹⁷ Thus, efforts to reduce unwarranted diagnostic testing in AGE are important to ensure that care is safe and effective.

The financial incentive for reducing diagnostic testing and potentially avoidable hospitalization is also important, with an annualized potential cost savings of

\$1 476 560 estimated from the population in our study. This estimate does not account for the additional expenses commonly associated with hospitalization, such as missed work days for caregivers; thus, the results are likely underestimated. Tieder et al¹⁸ showed that strict hospital adherence to national recommendations for diagnostic testing in children with AGE presenting for emergency care resulted in 50% lower charges and equivalent outcomes compared with hospitals with poor guideline adherence. Our study both confirms and extends these findings and shows that increased test utilization for AGE at the hospital level was associated with increased average costs and hospitalization rates.

The Centers for Medicare and Medicaid Services continues to work to link payment for the hospital stay to a value-based system in an effort to improve quality of care. Future research should be done to determine if delivering high-quality care efficiently reduces diagnostic testing and contains costs in gastroenteritis.

Wide variation in resource utilization also exists for bronchiolitis^{9,19} and pneumonia.^{10,20} Similar to AGE, these conditions are common in children and have consensus national practice guidelines.^{21,22} The variations in practice in bronchiolitis and pneumonia have been linked to differences in outcomes for patients. For bronchiolitis, variation in the management of hospitalized patients is associated with increased LOS.⁹ Increased diagnostic testing in pediatric patients with pneumonia has been linked to increased hospitalization rates without a decrease in ED revisits.¹⁰ Adherence to the published guidelines for both disease processes has been shown to reduce costs and resource utilization, as well as to decrease ED visits and hospitalizations, without negative impacts on disease outcomes.^{19,20}

Although adherence to national guidelines is associated with improved care, our data suggest that national guidelines alone are insufficient to reliably reduce diagnostic testing for AGE in US children. Local evidence-based guidelines have been shown to be successful in reducing variation in practice and improving quality of care provided in children with bronchiolitis¹⁹ and pneumonia²⁰ and febrile young infants.²³ Effective implementation of local clinical practice guidelines for AGE could affect physician ordering practices, thereby reducing diagnostic testing, resource utilization, and possibly ED LOS and admission for patients with AGE as well.^{24,25} It will be important to examine the impact of these local activities in future studies.

Several limitations of our study are worth mentioning. This study used administrative data; indications for diagnostic testing or reasons for admission were not available. Children with vomiting alone may be evaluated for other illnesses (eg, urinary tract infection, diabetic ketoacidosis) before confirming the diagnosis of AGE; thus, some diagnostic tests may be used to rule out alternative diagnoses. The PHIS database includes only tertiary children's hospitals, so our results may not be generalizable to all hospitals that care for pediatric patients with AGE, although previous studies have shown similar variations across different

settings for AGE and other conditions.^{7,26} To minimize the inclusion of diagnostic testing obtained after admission, we limited testing for hospitalized patients to the day of admission. However, we do not know if all diagnostic studies were obtained before the admission decision. We did not assess for differences in the use of antiemetics (eg, ondansetron) across hospitals. However, a previous PHIS study found no association between ondansetron use and rates of hospitalization, suggesting that the differences in hospitalization rates observed in our study are likely unrelated to the use of antiemetics.²⁷ Although we attempted to adjust for differences in hospital-level severity by using APR-DRG severity scores and patient characteristics, including age and payor and excluding children with complex chronic conditions, it is possible that other unmeasured differences may partially confound the relationship between the utilization of diagnostic studies and disposition.

CONCLUSIONS

Significant variation exists among US children's hospitals in diagnostic testing and hospitalization rates for children with AGE. Reducing diagnostic testing may decrease hospitalizations and costs without increasing ED revisits or readmissions. There is a need for continued efforts to better understand and eliminate unwarranted variation in pediatric AGE to ensure that care and outcomes are optimized for all children.

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