Clinical Impact of a Diagnostic Gastrointestinal Panel in Children

Jillian M. Cotter, MD, MSCS,[a] Jacob Thomas, MS,[b] Meghan Birkholz, MSPH,[c] Lilliam Ambroggio, PhD, MPH,[a,d] Jacqueline Holstein, BA,[e] Samuel R. Dominguez, MD, PhD[c]

abstract

OBJECTIVES: Many hospitals have transitioned from conventional stool diagnostics to rapid multiplex polymerase chain reaction gastrointestinal panels (GIP). The clinical impact of this testing has not been evaluated in children. In this study, we compare use, results, and patient outcomes between conventional diagnostics and GIP testing.

METHODS: This is a multicenter cross-sectional study of children who underwent stool testing from 2013 to 2017. We used bivariate analyses to compare test use, results, and patient outcomes, including length of stay (LOS), ancillary testing, and hospital charges, between the GIP era (24 months after GIP introduction) and conventional diagnostic era (historic control, 24 months before).

RESULTS: There were 12 222 tests performed in 8720 encounters. In the GIP era, there was a 21% increase in the proportion of children who underwent stool testing, with a statistically higher percentage of positive results (40% vs 11%), decreased time to result (4 vs 31 hours), and decreased time to treatment (11 vs 35 hours). Although there was a decrease in LOS by 2 days among those who received treatment of a bacterial and/or parasitic pathogen (5.1 vs 3.1; $P < .001$), this represented only 3% of tested children. In the overall population, there was no statistical difference in LOS, ancillary testing, or charges.

CONCLUSIONS: The GIP led to increased pathogen detection and faster results. This translated into improved outcomes for only a small subset of patients, suggesting that unrestricted GIP use leads to low-value care. Similar to other novel rapid diagnostic panels, there is a critical need for diagnostic stewardship to optimize GIP testing.

[a]*Department of Pediatrics, Sections of Hospital Medicine,* [c]*Infectious Diseases, and* [d]*Emergency Medicine, University of Colorado School of Medicine and Children's Hospital Colorado, Aurora, Colorado;* [b]*Adult and Child Consortium for Health Outcomes Research and Delivery Science, University of Colorado School of Medicine, Aurora, Colorado; and* [e]*Children's Hospital Colorado, Aurora, Colorado*

Drs Cotter and Dominguez conceptualized and designed the study, coordinated and supervised data collection and analyses, and drafted the initial manuscript; Mr Thomas conducted all analyses and assisted with interpretation of data; Ms Birkholz designed the data collection instruments, collected data, and assisted with interpretation of data; Dr Ambroggio assisted with data interpretation; Ms Holstein collected data and assisted with interpretation of data; and all authors reviewed and revised the manuscript, approved the final manuscript as submitted, and agree to be accountable for all aspects of work.

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Address correspondence to Jillian Cotter, MD, MSCS, Department of Pediatrics, Section of Hospital Medicine, Children's Hospital Colorado and University of Colorado School of Medicine, 13123 E 16th Ave, Box B302, Aurora, CO 80045. E-mail: jillian.cotter@childrenscolorado.org

WHAT'S KNOWN ON THIS SUBJECT: Many hospitals have transitioned from conventional stool diagnostics to more expensive multiplex gastrointestinal panels (GIPs) that can rapidly and simultaneously detect multiple pathogens. The clinical utility of this testing in children has not been evaluated.

WHAT THIS STUDY ADDS: The GIP led to increased detection, faster results, and faster antimicrobial initiation, which translated to improved outcomes for only a minority of patients. This highlights the critical need for diagnostic stewardship to optimize the value of the GIP.

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In children under the age of 5, diarrhea is the second leading cause of death worldwide.[1] In the United States, gastroenteritis and the resulting dehydration is a common reason for children to seek medical care and carries a large financial burden of >$350 million annually.[2–4] Infectious gastroenteritis can be caused by many types of enteric pathogens, including viruses, bacteria, and parasites; often, etiology can be difficult to identify given the overlap in clinical presentations.[5] Although pediatric gastroenteritis is generally a self-limited disease and guidelines do not endorse routine stool testing, some scenarios warrant testing.[6–8] Identification of organisms may assist in treatment decisions, allow for monitoring of potential complications, and augment infection control interventions.[6,7] In some cases, treatment may decrease symptom duration and risk of complications.[6,7] Thus, there is a need for early and accurate identification of causative organisms, which is an unmet clinical and public health need.[9,10]

Over the last decade, many hospitals have transitioned from conventional stool diagnostics, including culture, serology, and immunofluorescence assays to more expensive testing modalities, such as nucleic acid amplification multiplex diagnostic panels. The BioFire FilmArray Gastrointestinal Panel (GIP) (BioFire Diagnostics, Salt Lake City, UT) is an example of a multiplex polymerase chain reaction (PCR) syndromic panel that is now widely available, and there are several similar tests used clinically. These tests allow for rapid, highly sensitive results of >20 different organisms simultaneously, including bacteria, parasites, and viruses.[11]

The introduction of new diagnostic technology presents unique opportunities and challenges to diagnostic and antibiotic stewardship efforts.[12] Overuse of new diagnostics can raise costs without significantly impacting clinical care. Thus, it is critical to evaluate the utility of emerging technologies such as the GIP. Previous studies GIP in adults demonstrate improved sensitivity, faster result time, and improved laboratory workflow with GIP testing.[13,14] However, the clinical utility of the GIP still remains unanswered.[15,16] No studies have evaluated the clinical utility of the GIP in a large pediatric population. Thus, the aims of this study were to (1) compare stool test use, pathogen detection, and time to result and (2) evaluate the clinical impact of GIP testing on patient outcomes, including the length of stay (LOS) and resource use between GIP and conventional diagnostic testing in a large pediatric population.

METHODS

Study Design and Population

We performed a cross-sectional cohort study of children ≤18 years of age who had stool testing performed from 2013 to 2017 and analyzed in the Children's Hospital Colorado microbiology laboratory. This included patient encounters in the inpatient, emergency department and urgent care (ED/UC), and ambulatory settings associated with a large, freestanding, quaternary-care, urban, academic children's hospital and 4 affiliated community-based children's hospitals.

Data Sources and Collection

Patient encounters with stool testing were identified from the electronic medical record (EMR) (Epic, Verona, WI). Patient demographics, clinical characteristics, diagnostic workup, and stool tests were obtained from the EMR. For hospitalized children with a bacterial and/or parasitic stool pathogen, we determined the use of antimicrobial agents via chart review. We obtained hospital charges from the finance department. To adjust for patient volume changes over the study period, we calculated the number of patient encounters for all inpatient, ambulatory, and ED/UC sites that sent stool testing over the study period. This study was approved by the Colorado Multiple Institutional Review Board.

Stool Testing

The explanatory variable was the type of stool testing available. The GIP was introduced in October 2015, and the GIP era included the 24 months thereafter (November 1, 2015–October 31, 2017). Outcomes were compared between the GIP era and historic controls in the conventional diagnostic era, which included the 24 months previous (October 1, 2013–September 30, 2015). A 1-month period after introducing the GIP was excluded to allow for uptake of new testing.

Both eras tested for bacteria, parasites, and viruses but had different testing modalities, with varying sensitivities and pathogens that could be identified (Table 1). In the conventional diagnostic era, testing included *Giardia* and *Cryptosporidium* direct fluorescent antigen (Meridian Bioscience, Cincinnati, OH), ova and parasites, *Clostridiodes difficile* PCR (Xpert *C difficile*; Cepheid, Sunnyvale, CA), bacterial culture, and viral electron microscopy (Table 1). In the GIP era, GIP replaced the need for most other testing. The FilmArray GIP (BioFire Diagnostics) detects 22 enteric pathogens, including bacteria, viruses, and parasites (Table 1). To provide antibiotic susceptibilities, stool cultures were additionally performed when the GIP was positive for *Shigella* or *Salmonella.* Other stool tests available in the GIP era included ova and parasites and *C difficile* PCR, which were offered in both eras.

Testing for gastrointestinal pathogens was part of routine clinical care; there were no official guidelines for testing. The laboratory did not perform tests

TABLE 1 Gastrointestinal Pathogens Detected in Each Era

	Bacteria	Parasites	Viruses
Conventional diagnostic era	*C difficile* toxin[a]	*Cryptosporidium*[b]	Adenovirus[c]
	Aeromonas[d]	*Giardia lamblia*[b]	Rotavirus[c,e]
	β-hemolytic *Streptococcus*[d]	*Ascaris lumbricoides*[f]	Small round virus[c]
	Campylobacter[d]	*Blastocystis hominis*[f]	Torovirus[c]
	Enteroinvasive *E coli and Shigella*[d]	*Dientamoeba fragilis*[f]	
	Methicillin-susceptible *Staphlococcus aureus*[d]	*Entamoeba histolytica*[f]	
	Plesiomonas[d]		
	Pseudomonas[d]		
	Salmonella[d]		
	Shiga toxin–producing *E coli*[d]		
	Yersinia[d]		
GIP era[g]	*C difficile* toxin[a,h]	*Cryptosporidium*[h]	Adenovirus[h]
	Campylobacter[h]	*Cyclospora*[h]	Astrovirus[h]
	Enteroinvasive *E coli* and *Shigella*[h]	*E histolytica*[f,h]	Norovirus[h]
	Plesiomonas[h]	*G lamblia*[h]	Rotavirus[h]
	Salmonella[h]	*A lumbricoides*[f]	Sapovirus[h]
	Shiga toxin–producing *E coli*[h]	*B hominis*[f]	
	Vibrio cholerae and *Vibrio cholerae*[h]	*D fragilis*[f]	
	Yersinia[h]		

Included all pathogens that were identified over the 4-year study period.
[a] *C difficile* PCR (Xpert *C difficile*; Cepheid).
[b] *Giardia* and *Cryptosporidium* direct fluorescent antigen (Meridian Bioscience).
[c] Viral electron microscopy.
[d] Bacterial culture.
[e] Consistent with norovirus.
[f] Ova and parasites.
[g] Enteropathogenic, enteroaggregative, and enterotoxigenic *E coli* are additional bacterial pathogens detected by GIP testing but were not included because these organisms are not reported in the EMR, given their unknown clinical significance.[17–19]
[h] GIP (BioFire Diagnostics).

on formed stools, and there were no testing policy changes during the study period. In our analysis, we only included stool results that were released in the EMR and available to providers. Detection of enteropathogenic, enteroaggregative, and enterotoxigenic *Escherichia coli* on the GIP were not released unless specifically requested, given the unknown clinical significance of these pathogens in children in the United States.[17–19] Similarly, *C difficile* results from GIPs were not released for children <1 year of age because of concern for asymptomatic colonization.[20]

Outcomes and Other Definitions

The primary outcomes were LOS and resource use. These outcomes were evaluated in patients hospitalized with community-acquired diarrhea, defined as patients with stool testing collected within the first 72 hours of hospitalization and LOS of <14 days. By evaluating this subset of patients, we focused on patients presenting with diarrheal symptoms and excluded those with prolonged admissions for reasons other than gastroenteritis. Resource use included the mean number of ancillary laboratory tests performed, percent of patients with at least 1 abdominal imaging study, and total hospital charges. Ancillary laboratory testing included tests for electrolytes, inflammatory markers, complete blood counts, and bacterial blood culture. Ancillary imaging included abdominal studies (Supplemental Table 6). To focus on the impact of stool results on ancillary testing, we only included testing performed 1 to 7 days after stool collection. To account for inflation, hospital charges were adjusted to 2018 prices, with a 6% per year increase per unit charge.

Secondary outcomes included stool test use, pathogen detection, time to result, and time to treatment. All secondary outcomes, other than time to treatment, were evaluated in the overall population, including tests performed in ambulatory and ED/UC settings. Stool test use was defined as the number of patients who received at least 1 stool test and the total number of stool tests performed as raw numbers and proportions over patient volume per era. Pathogen detection included the number of positive results and percent positivity, defined as the percent of tests positive for a given pathogen out of the total number of tests performed that were capable of detecting that pathogen. Time to result was defined as time from stool collection to the release of results in the EMR. Time to treatment was defined as the time from stool collection to administration of the first antimicrobial agent that was given after stool collection and had an order indication (required for all antibiotics) for "acute gastroenteritis/sepsis."[21] We evaluated this outcome among children without complex chronic conditions (CCCs) who were hospitalized with community-acquired diarrhea and had test results positive for a bacterial and/or parasitic stool pathogen.[22] We did not compare time to treatment between the eras for tests positive for *C difficile* because the testing modality for *C difficile* did not change between eras and impact of the GIP on *C difficile* has been previously described.[23] Encounters were organized into 3 hospital settings on the basis of the highest level of care that patients required: inpatient, ED/UC, or ambulatory.

Statistical Analysis

For the descriptive analyses, categorical variables were displayed as frequencies and percentages, and

continuous variables were displayed as medians and interquartile ranges (IQRs). We used bivariate analyses to compare outcome variables between the 2 eras using Pearson's χ^2 test (for categorical variables) or the Wilcoxon rank test (for medians). LOS and resource use outcomes were evaluated in hospitalized patients with community-acquired diarrhea as well as non-CCC subgroups identified a priori on the basis of pathogen type and those who received treatment with antimicrobial agents. We did not adjust for seasonal variability because both eras spanned the same calendar months. All analyses were performed by using SAS version 9.4 (SAS Institute, Inc, Cary, NC), and *P* values of <.05 were considered statistically significant.

TABLE 2 Sociodemographic and Clinical Characteristics of Patients With Stool Testing

Variable	Overall (*N* = 8720)	Conventional Diagnostic Era (*n* = 3890)	GIP Era (*n* = 4830)	*P*
Age, y, median (IQR)	6.0 (1.0–12.0)	6.0 (1.0–12.0)	6.0 (1.0–12.0)	.42
<1 y old, *n* (%)	1173 (14)	501 (13)	672 (14)	.16
Sex, female, *n* (%)	3902 (45)	1687 (43)	2215 (45)	.02
Ethnicity, *n* (%)				.30
Not Hispanic or Latino	5854 (67)	2588 (66)	3266 (68)	
Hispanic or Latino	2494 (29)	1143 (29)	1351 (28)	
Unknown	372 (4)	159 (4)	213 (4)	
Financial class, *n* (%)				.02
Government	4159 (48)	1790 (46)	2369 (49)	
Private	4397 (50)	2021 (52)	2376 (49)	
Self-pay	164 (2)	79 (2)	85 (2)	
CCC[a], *n* (%)	3496 (40)	1499 (39)	1997 (41)	.008
Hospital setting, *n* (%)				.16
ED/UC	1791 (21)	831 (21)	960 (20)	
Ambulatory	3525 (40)	1538 (40)	1987 (41)	
Inpatient	3404 (39)	1521 (39)	1883 (39)	
ICU[b]	1066 (31)	486 (32)	580 (31)	.47
Time of initial stool collection relative to admission[b]				
≤72 h, *n* (%)	2185 (64)	971 (64)	1214 (65)	.70
Median time, d (IQR)	1.5 (0.4–5.3)	1.6 (0.4–5.1)	1.5 (0.5–5.3)	.94

N represents number of patient encounters with any stool testing.

[a] See Reference 22.

[b] For inpatient encounters only.

RESULTS

Stool Test Use

There were 12 222 stool tests performed in 8720 patient encounters among 6733 unique patients. A total of 40% of patients were in the ambulatory setting, and 60% did not have a CCC (Table 2). There were similar patient characteristics between the 2 eras. In the GIP compared with conventional diagnostics era, the proportion of stool tests performed per patient volume decreased by 23% (total stool tests: 5402 from 6820), but the proportion of encounters that had stool testing per patient volume increased by 21% (total encounters with stool testing: 4830 from 3890; *P* values <.001). A higher percentage of encounters had only 1 stool test in the GIP, compared with the conventional diagnostic era (92% vs 54%; $P < .001$).

Pathogen Detection

In the GIP era, there was more testing performed capable of detecting bacteria, viruses, and parasites, and more positive results for each pathogen type (Table 3). There was a higher percent positivity overall in the GIP era (40% vs 11%; $P < .001$), with an increased percent of positivity for viruses but decrease for bacteria. The most common pathogens detected in each era included *C difficile, Salmonella*, *Campylobacter*, Shiga toxin–producing *E coli*, and *G lamblia* in the conventional diagnostic era and *C difficile*, norovirus, sapovirus, rotavirus, and adenovirus in the GIP era (Table 3). In the GIP era, a higher percentage of patients had >1 organism detected (8.6% vs 0.4%; $P < .001$). For patients with a positive GIP result, most had a virus (54%), with a lower frequency of *C difficile* (38%), other bacteria (18%), and parasites (5%) detected.

Time Outcomes

In the GIP era, compared with the conventional diagnostic era, the median time to result decreased by over 24 hours (4 vs 31 hours; $P <$ .001). Across both eras, there were 58 children hospitalized with community-acquired diarrhea who had enteric bacteria (excluding *C difficile)* and/or parasites and received antimicrobial agents. This represented 2.9% of the tested patients hospitalized with community-acquired diarrhea, with a higher percentage in the GIP, compared with the conventional diagnostic era (3.7% vs 1.9%; $P =$ .02). For these patients, the time to treatment decreased by 25 hours in the GIP era (11 vs 36 hours; $P < .001$).

LOS

LOS and resource use were evaluated among 1986 children hospitalized with community-acquired diarrhea (885 in the conventional diagnostic era and 1101 in the GIP era) and in non-CCC subgroups on the basis of stool test results and antimicrobial administration (numbers per group are displayed in Fig 1). For hospitalized patients who received antimicrobial agents for a bacterial and/or parasitic pathogen, LOS decreased by 2 days (3.1 vs 5.1; $P <$ .001; Table 4). However, there was

TABLE 3 Stool Testing and Results by Era

Pathogens	Conventional Diagnostic Era (n = 6820)			GIP Era (n = 5402)			P
	Positive Results, n	Tested, n	Percent Positivity, %[a]	Positive Results, n	Tested, n	Percent Positivity, %[a]	
Pathogen type							
Any pathogen	733	6820	11	2173	5402	40	<.001
Bacteria[b]	232	2140	11	388	4739	8	<.001
Virus[c]	35	562	6	1173	4739	25	<.001
Parasite[d]	45	1758	3	109	4928	2	.40
Most common pathogens[e]							
Norovirus[f]	5	562	1	472	4739	10	—
Sapovirus	0	0	0	272	4739	6	—
Rotavirus	15	562	3	221	4739	5	—
Adenovirus	10	562	2	175	4739	4	—
Astrovirus	0	0	0	165	4739	4	—
Salmonella	74	2140	3	125	4739	3	—
Campylobacter	56	2140	3	120	4739	3	—
Shiga toxin–producing *E coli*	49	2140	2	96	4739	2	—
G lamblia	28	1758	2	68	4928	1	—
Enteroinvasive *E coli* and *Shigella*	11	2140	1	41	4739	1	—

n represents the number of tests. —, not applicable.

[a] Percent positivity is defined as the number of tests positive for any organism divided by number of tests performed that are capable of detecting that pathogen.

[b] Performed with a bacterial culture in the conventional diagnostic era and the GIP in the GIP era; the No. positive results and percent positivity exclude *C difficile*–positive results (because the impact of the GIP on *C difficile* is already described in a previous article[23]).

[c] Performed with viral electron microscopy in the conventional diagnostics era and with the GIP in the GIP era.

[d] Performed with a *Giardia* and *Cryptosporidium* or ova and parasites test in the conventional diagnostics era and GIP or ova and parasites in the GIP era.

[e] Top 10 most common pathogens (excluding *C difficile*) identified in the GIP era in descending order; additional top 10 pathogens in the conventional diagnostic era that are not displayed above include *Pseudomonas* (positive results, n = 13) and β-hemolytic *Streptococcus* (positive results, n = 11).

[f] Small round virus from viral electron microscopy is consistent with norovirus.

no difference in LOS for all patients, regardless of stool test results (Table 4).

Resource Use

There was no difference in ancillary laboratory tests or imaging studies between eras (Table 5). For patients with test results positive for a bacterial and/or parasitic pathogen who received antimicrobial agents, there was a significant decrease in median hospital charges in the GIP era by nearly $20 000 ($P < .001$). There was also a decrease in charges for children without CCCs by ~$3000 ($P = .04$), but there were no differences in charges for all patients (Table 5).

DISCUSSION

In a large pediatric study evaluating the impact of the GIP, we found more patients who underwent stool testing but a reduction in the number of individual stool tests performed, increased pathogen detection, and more rapid results. In patients with test results positive for bacterial or parasitic enteric organisms, faster results led to quicker initiation of antimicrobial agents, and those who received therapy had a decreased LOS and lower hospital charges. However, for the majority of patients, the GIP had no impact on LOS, ancillary testing, or charges. This highlights the critical need for diagnostic stewardship to better define and implement testing criteria to optimize the value of multiplex stool testing.

We identified several benefits of multiplex PCR stool testing, compared with conventional diagnostics. First, it was convenient for providers to order and the microbiology laboratory to perform 1 test per patient, instead of multiple. Second, GIP testing led to improved pathogen detection, with over 3 times the number of positive results compared with conventional diagnostics. This increase is likely due to improved sensitivity, increased testing, and improved case-finding with multiple pathogens on the panel, thereby eliminating the need for selective ordering.[11,14] Although the percent of positivity for bacterial pathogens decreased with the GIP, compared with bacterial culture in the conventional diagnostic era, this is likely because of reduced pretest probability as other studies have demonstrated high sensitivity of the GIP.[11] Third, GIP results were available to clinicians in under 5 hours, which was more than 24 hours earlier than with conventional diagnostics. These improvements in pathogen detection and result time are similar to findings in adult studies.[13,14,16] Our GIP result time was faster than the 9 to 41 hours reported in the literature, likely because our laboratory runs GIPs 24 hours per day and 7 days per week.[13,14,16] The rapid result time maximizes the potential for clinically relevant results to optimally influence patient care.[12]

Although increased pathogen detection and faster result times are beneficial attributes of a diagnostic test, these benefits should ideally translate to improved patient outcomes or a reduction in health care use. We found that, in a small subset of patients hospitalized with community-acquired diarrhea who had test results positive for bacterial or parasitic pathogens and received antimicrobial therapy, use of the GIP led to quicker initiation of therapy

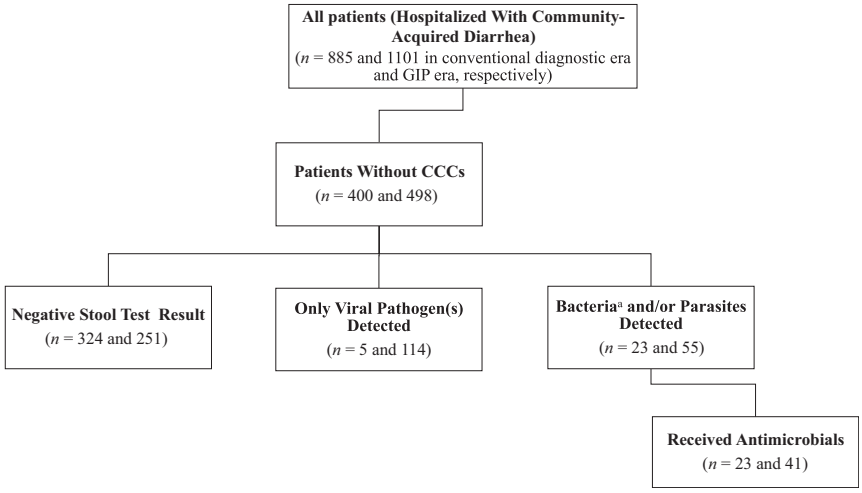

FIGURE 1

The number of patients hospitalized with community-acquired diarrhea by CCC categorization, test results, receipt of antimicrobials, and era. This figure displays the number of children hospitalized with community-acquired diarrhea who had stool testing in the conventional diagnostic era and GIP era. The figure also shows the number of patients in each subgroup, which was used to evaluate LOS and resource use outcomes. [a] Excludes *C difficile*.

(more than 24 hours earlier), decreased LOS (by 2 days), and lower hospital charges (nearly $20 000 per patient). Similarly, in adult studies, researchers have found that the GIP facilitated faster time to treatment.[14] We hypothesize that faster results allowed clinicians to start treatment sooner, which resulted in more rapid symptom resolution. However, these improved outcomes were only found in 3% of tested patients because of the low frequency of patients with bacterial and parasitic gastroenteritis who received treatment.[7] Although there was a statistically significant decrease in charges for children without CCCs in the GIP era, likely related to a decrease in LOS, this is relatively small and likely not financially significant.

For the overall population, the GIP's improved detection and rapid turnaround time did not impact outcomes. The only other pediatric study to evaluate the impact of GIP testing on LOS did so in a small cohort of 61 patients and found a similar LOS, also with no difference based on testing type.[13] We hypothesize that this is because discharge readiness and LOS are closely tied to symptom improvement. Given that a majority (60%) of GIP results were negative, suggesting a noninfectious etiology or untested pathogen, and most of the positive results were viral, management with supportive care was likely not modified in response to these results. Knowing that the patient had an infectious cause of their symptoms did not appear to facilitate earlier discharge, supported by the findings of another study.[8] Additionally, providers may have limited experience with some viruses detected on the GIP (eg, sapovirus) and thus may be unsure what this additional information means for patients and their management. The use of ancillary testing was not different between the 2 cohorts, likely because ancillary testing is relatively uncommon and dictated by continued symptoms. Finally, we found no financially significant differences in charges. Although, in some adult studies, researchers note decreased abdominal studies and cost saving with GIPs, these findings are likely not generalizable to children, given the self-limited nature of most pediatric diarrhea, relatively low occurrence of imaging studies, and fact that pediatric infection control practices are more commonly driven by symptoms in addition to testing results.[13,15,16,24]

Our findings highlight the critical need for diagnostic stewardship to optimize the value of the GIP. We found high test use, particularly in children not sick enough to warrant hospitalization and in those without medical complexity, in which the risk for treatable bacterial or parasitic infections is less common.[25] This may be because of simplified clinician ordering, readily available testing, GIP novelty, and the perception that faster turnaround time would be more clinically beneficial. Given the high cost of GIPs and small percentage of tested patients with improved outcomes, further studies are needed to better predict those who are likely

TABLE 4 LOS for Hospitalized Patients With Community-Acquired Diarrhea

Time Outcome and Population	Conventional Diagnostic Era, d, Median (IQR)	GIP Era, d, Median (IQR)	*P*
All patients	3.5 (2.1–5.9)	3.3 (2.0–5.8)	.11
Patients without CCCs[a]	2.9 (1.9–4.7)	2.7 (1.7–4.3)	.08
Negative stool test results[b]	2.9 (1.8–4.7)	3.1 (1.8–5.8)	.34
Only viral pathogen(s) detected[b]	1.9 (1.7–3.7)	2.2 (1.6–3.2)	.96
Bacteria[c] and/or parasites detected[b]	2.6 (1.9–5.7)	2.5 (1.7–4.0)	.17
Received antimicrobial agents[d]	5.1 (3.8–6.0)	3.1 (2.0–4.7)	<.001

The number of patients represented in each group is displayed in Fig 1.

[a] See Reference 22.

[b] Subset of patients without CCCs

[c] Excluding *C difficile*

[d] Subset of patients without CCCs who had bacteria (excluding *C. difficile*) and/or parasites detected.

TABLE 5 Resource Use for Hospitalized Patients With Community-Acquired Diarrhea

Outcome and Population	Conventional Diagnostics Era	GIP Era	*P*
Ancillary laboratory tests, median (IQR)			
All patients	2.0 (0.0–6.0)	2.0 (0.0–6.0)	.74
Patients without CCCs[a]	1.0 (0.0–4.0)	1.0 (0.0–3.0)	.99
Bacteria[b] and/or parasites detected[c]	2.0 (0.0–3.0)	2.0 (1.0–5.0)	.35
Received antimicrobial agents[d]	4.0 (2.0–9.0)	3.0 (1.0–7.0)	.42
≥1 ancillary imaging study, *n* (%)			
All patients	348 (39)	419 (38)	.57
Patients without CCCs[a]	163 (41)	186 (37)	.30
Bacteria[b] and/or parasites detected[c]	6 (26)	16 (29)	.79
Received antimicrobial agents[d]	9 (53)	13 (32)	.13
Hospital charges, $, median (IQR)			
All patients	40 769.4 (25 003.1–70 923.8)	38 527.8 (23 995.4–67 287.0)	.11
Patients without CCCs[a]	31 991.2 (21 668.0–50 059.1)	29 041.4 (19 267.5–48 877.4)	.04
Bacteria[b] and/or parasites detected[c]	33 888.6 (24 088.8–47 141.8)	24 655.4 (19 218.6–39 544.0)	.08
Received antimicrobial agents[d]	47 141.8 (38 316.3–67 779.0)	28 328.8 (21 000.9–48 877.4)	<.001

The number of patients represented in each group is displayed in Fig 1.

[a] See Reference 22.

[b] Excluding *C difficile*

[c] Subset of patients without CCCs

[d] Subset of patients without CCCs who had bacteria (excluding *C. difficile*) and/or parasites detected.

to benefit from stool testing. This will enable hospitals to develop testing guidelines to inform providers and optimize the value of the GIP. Implementation studies to understand the optimal diagnostic stewardship approach and ways to balance these interventions with physician autonomy are also needed.

These findings are similar to studies on other emerging rapid diagnostics, such as the meningitis encephalitis and respiratory panels, highlighting a systemic challenge with multiplex diagnostics.[12,26] Although rapid diagnostics are revolutionizing the way we test for and detect infectious pathogens, there are significant practical challenges that exist.[12] As new tests are introduced into clinical practice, it is critical that diagnostic stewardship is rolled out in parallel to combat the natural tendency to overuse and overestimate their benefits.[12] Given the added costs of these rapid diagnostics, it is also important to evaluate the cost-effectiveness and clinical impact of novel diagnostics to inform testing strategies and optimize high-value care.[12,27,28]

There are several limitations of this study. First, our findings are limited to 4 hospitals within a single health care system, which may limit generalizability. However, by including quaternary-care teaching hospital and satellite community hospitals, our cohort included both complex and previously healthy children. Second, we used historical controls and therefore there may have been institutional changes between the eras that unknowingly influenced our outcomes.

CONCLUSIONS

In this large pediatric study, we demonstrated that the introduction of the GIP led to increased pathogen detection and faster results. This translated into improved outcomes for only a small minority of patients, suggesting that unrestricted use of the GIP leads to low-value care. Similar to other novel rapid diagnostic panels, there is a critical need for diagnostic stewardship to optimize the value of the GIP.

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ABBREVIATIONS

CCC: complex chronic condition
ED/UC: emergency department and urgent care
EMR: electronic medical record
GIP: gastrointestinal panel
IQR: interquartile range
LOS: length of stay
PCR: polymerase chain reaction

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